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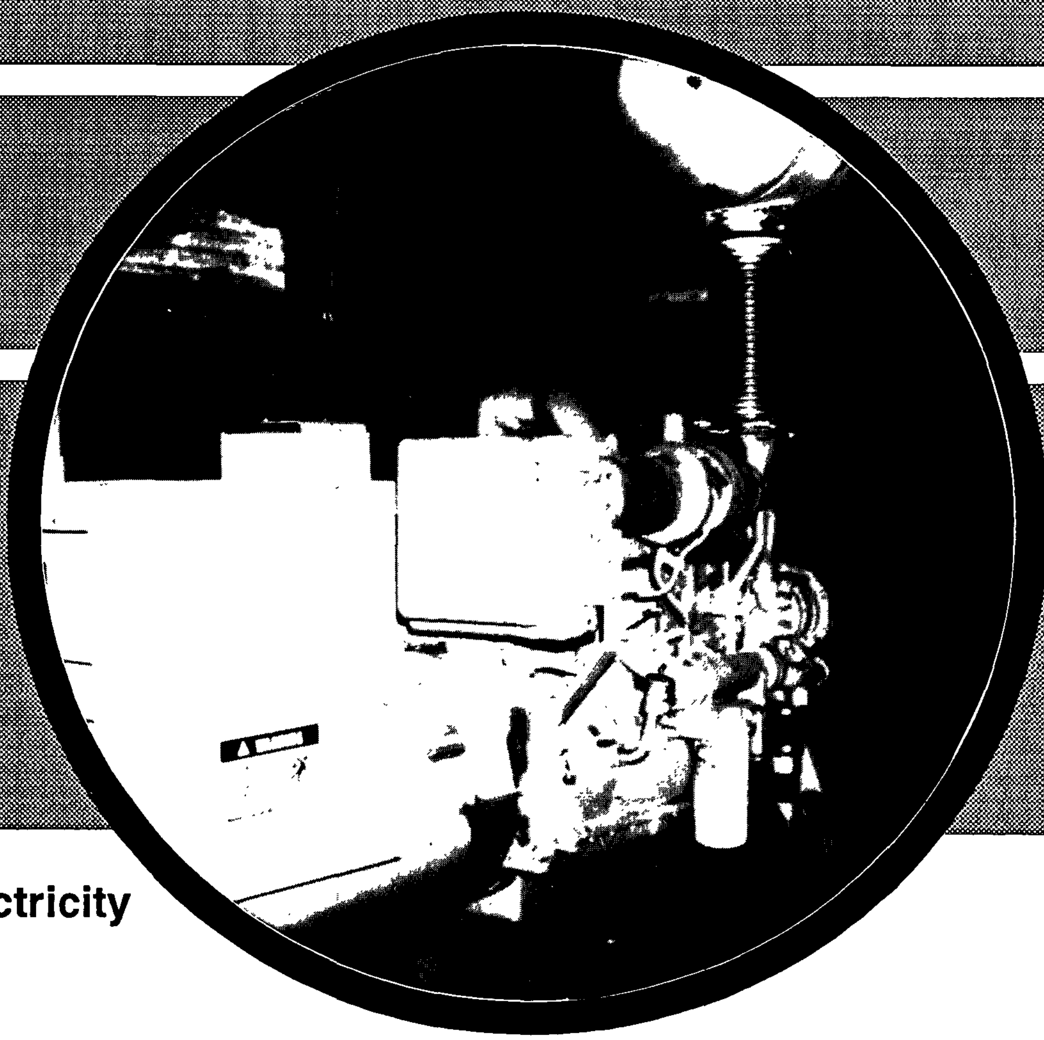
Industrial Uses Of Agricultural Materials

Situation and Outlook Report



Generating electricity from biogas.

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Summaries and text may be accessed electronically through the USDA CID System; for details, call (202) 720-9045.

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Mention of private firms or products does not indicate endorsement by USDA. Cover photo is of an engine generator, which uses biogas to produce electricity, on Mason Dixon Farms in Gettysburg, PA (see special article).

Market Conditions and Research Increase Industrial Use of Agricultural Materials

During fiscal 1993-94, USDA's Alternative Agricultural Research and Commercialization (AARC) Center used $15.3 million to fund 39 projects. Private partners contributed another $43 million, resulting in a private-public funding ratio approaching 3 to 1. The AARC Board recently met and made the initial round of fiscal 1995 project selections from approximately 100 applications. USDA's Cooperative State Research, Education, and Extension Service is working with the U.S. Department of Defense to develop advanced materials from renewable resources. To date, USDA's Agricultural Research Service has negotiated over 425 cooperative research and development agreements with industrial partners. U.S. Department of Energy's Alternative Feedstocks Program has developed a thermal/chemical clean fractionation process that is being evaluated by industry.

The U.S. gross domestic product and industrial production are expected to grow 3.9 and 5.6 percent, respectively, in 1994. Growth, however, is forecast to slow in 1995. Industrial markets for agricultural products should continue to grow, albeit more slowly.

Despite the Court stay on the U.S. Environmental Protection Agency's renewable oxygenate requirement, high methanol prices and a recent Treasury Department announcement that ethyl tertiary butyl ether (ETBE) is eligible for excise tax exemption could push ethanol production close to 1.5 billion gallons in 1995. Industrial uses of corn in 1994/95 are forecast up 12 percent from 1993/94. Most of the increase is expected to be used to make ethanol. Corn also is used to produce sorbitol, a polyol widely used in personal-care products.

Meadowfoam, a new oilseed crop grown in Oregon, contains a unique oil that is used in cosmetics and has potential in other applications. Recent plant breeding, agronomic research, and oil-product development are bringing meadowfoam closer to commercial viability. Polyols, which are traditionally derived from petrochemicals, are now being made from vegetable oils.

Composite products are an important and growing segment of the forest products industry. Over 70 percent of all wood materials in use today contain some type of adhesive, and that figure is expected to grow as new products and processes are developed. As supplies of virgin timber tighten, nonwood biomass fibers, such as straw, and recycled fiber products, such as paper and wood wastes, are being used as raw materials for composite products.

Relatively recent technological developments have allowed improved screening of plants for potentially beneficial chemical compounds. Both public and private sectors have responded by beginning natural-products drug research. Markets for herbal remedies have also expanded, driven by increasing interest in health and alternative medicines.

Livestock producers who operate large-scale confinement operations, such as dairies and hog farms, are looking for ways to handle and dispose of animal wastes that are cost effective and meet odor and pollution regulations. Farm-level production of biogas (using anaerobic digesters) is one solution that also will help control methane emissions into the atmosphere. With current technologies, anaerobic digesters generally require warm climates, large volumes of manure, high local electricity rates, and daily maintenance and management to be profitable. "Biogas Production from Animal Manures: What Is the Potential?" covers these issues and describes four case studies that demonstrate the feasibility of farm-level production of biogas.

The second special article is "Pulping Catalysts From Lignin." Lignin, a common material in trees and woody plants, currently is a byproduct of pulp and paper production. However, joint research at the National Renewable Energy Laboratory and the Institute of Paper Science and Technology is aimed at broadening commercial uses of lignin. One project is assessing the potential for converting lignin into anthraquinone-like pulping catalysts. Anthraquinone (AQ) improves kraft pulping, but its cost hinders widespread use. Three processes were evaluated for their technical and economic feasibility of converting lignin into pulping catalysts. Preliminary results indicate that two of the processes appear viable. Comparing these two processes to competing petrochemical-based, AQ-producing methods, showed that the lignin-based routes were potentially the most cost effective.

Development and Commercialization of Biobased Materials Continue

USDA's Alternative Agricultural Research and Commercialization Board recently made initial selections of projects to be funded in fiscal 1995. USDA's Cooperative State Research, Education, and Extension Service is working with the U.S. Department of Defense to develop advanced materials from renewable resources. To date, USDA's Agricultural Research Service has negotiated over 425 cooperative research and development agreements with industrial partners. DOE's Alternative Feedstocks Program has developed a thermal/chemical clean fractionation process that is being evaluated by industry.

Updates: USDA's AARC Center

During fiscal 1993-94, USDA's Alternative Agricultural Research and Commercialization (AARC) Center used $15.3 million to fund 39 projects. Private partners contributed another $43 million, resulting in a private-public funding ratio approaching 3 to 1. The Center requires at least a 50-percent match in funds and negotiates a payback arrangement for each project. The Center received $6.5 million in funding for fiscal 1995. The AARC Board met December 5-7, 1994, in Kansas City, MO, and made the initial round of 1995 project selections from approximately 100 applications.

In September 1994, Secretary of Agriculture Mike Espy announced a cooperative agreement between the AARC Center and the National Association of State Departments of Agriculture to provide outreach for the Center in all 50 states. Local entrepreneurs and other parties interested in the AARC Center program may now contact their local state department of agriculture for information. In addition, state officials can help identify and assist the Center with worthy projects.

The AARC Center completed its fiscal 1994 project funding by supporting two projects in Georgia and Texas. (See the June 1994 issue of this report for information on projects funded earlier this year.) The first project is with BioPlus, Inc., of Ashburn, GA. The company is using waste peanut hulls as a carrier for crop-protection compounds and, now, as cat litter. The hulls are run through a hammer mill and pelletized for the appropriate use. AARC Center funds are being used to develop and implement a marketing plan for the cat litter, which is 100-percent biodegradable, holds twice as much moisture as conventional clay litter, and is flushable.

The second project is with Indian Creek Mesquite of Brownwood, TX. The company is processing mesquite chips and marketing them as an environmentally friendly and taste-enhancing alternative to charcoal. The mesquite is coated with U.S. Food and Drug Administration-approved paraffin to help it burn, but contains no noxious hydrocarbons as does some charcoal. The product meets stringent California clean air requirements. AARC Center funds are being used to upgrade the facility and develop a marketing program for the product. The company is using only larger mesquite trees, leaving the smaller ones for harvest in later years.

Most CSREES Programs Continue

Industrial use programs administered by USDA's Cooperative State Research, Education, and Extension Service (CSREES) were funded for fiscal 1995, with the exception of the high erucic acid development effort. (Under the Federal Crop Insurance Reform and Department of Agriculture Reorganization Act of 1994 [P.L. 103-354], the Cooperative State Research Service was merged with the Extension Service and renamed CSREES). The Advanced Materials from Renewable Resources Program, jointly administered by CSREES and the U.S. Army Natick Laboratory, was funded at $5 million, the same as 1994. A portion of the funds is being utilized to test agricultural products in U.S. Department of Defense facilities. These tests include guayule rubber tires and biodiesel at the Army's proving grounds in Yuma, AZ, and spill adsorbents, solvents, cutting oils, peelable coatings, and packaging foams at the U.S. Army Tank and Automotive Research, Development, and Engineering Center in Warren, MI.

CSREES's industrial uses program recently displayed its accomplishments at two major technology exhibitions: Technology 2004, November 8-10, 1994, in Washington, DC, and the Biobased Products Expo '94, December 5-7, 1994, in Kansas City, MO. Vernonia, lesquerella, kenaf, and guayule were featured in the display.

ARS Marks a Decade of Formal Technology Transfer Activities

In 1984, USDA's Agricultural Research Service (ARS) published its first official technology transfer plan, which called for active interaction of agency scientists with industry to get ARS research results commercialized. Passage of the Federal Technology Transfer Act of 1986 gave the ARS technology-transfer program further impetus. Under the act, ARS has negotiated over 425 Cooperative Research and Development Agreements (CRADA's) with industrial partners and pursued strong patenting and licensing efforts. ARS is among the top three or four Federal agencies in terms of the number of CRADA's signed.

During the first decade of its existence, the technology-transfer program facilitated the commercialization of at least a dozen new products from ARS research. These successes include low-calorie, high-fiber baking products from oat hulls, Oatrim (a fat substitute made from oat flour), biodegradable plastics from cornstarch, starch-based encapsulated pesticides, enzymatically assisted, peeled-and-sectioned citrus products, and lactose-free milk. End products containing these items account for hundreds of millions of dollars in sales annually. For example, Oatrim was incorporated into $1 billion worth of "Healthy Choice" consumer products within 18 months of patent issue.

ARS signed 93 CRADA's in fiscal 1994, compared with 59 the previous year. An agreement with Franz Haas Machinery of Richmond, VA, is to develop biodegradable, water-resistant coating products made with 100-percent potato or cornstarch. As part of the CRADA, ARS scientists are evaluating several natural biodegradable polymers to make items such as foam cups, plates, and packaging that deter moisture absorption.

The agency filed 40 patent applications in fiscal 1994, down from 68 in 1993. An example of a 1994 application is a process to manufacture nonallergenic rubber latex from domestic plant species such as guayule, milkweed, and goldenrod (see the specialty plant products section for more information). Licensing of the technology is underway.

In fiscal 1995, ARS received $79.5 million for research and development of new uses for agricultural commodities, the same as last year. Of this, $45.3 million is allocated to new, nonfood uses and $34.2 million to new foods and processing systems. A major benefit of the interactions facilitated by CRADA's and patent licenses is the feedback from industrial partners that helps the agency prioritize its research program to get the biggest bang for taxpayer dollars.

DOE's Alternative Feedstocks Program Reaches a Major Milestone

The U.S. Department of Energy's (DOE) Alternative Feedstocks Program (AFP), administered by the Office of Industrial Technologies, marked its first year and a half of research and development of technologies that convert renewable resources into chemicals. An objective of AFP is to demonstrate, through industrial partnerships, the commercial feasibility of biobased processes. Currently under development are two processes: One involves an organic acid (to demonstrate production of a high-volume intermediate chemical from a renewable resource), while the other uses lignocellulosic materials (to demonstrate an improved clean-fractionation-of-biomass technology).

The lignocellulosic project, which uses thermal/chemical clean fractionation, has reached a major milestone. DOE's National Renewable Energy Laboratory has demonstrated, on a laboratory scale, the ability of the process to produce cellulose and cellulose derivatives of interest to industry. This project has the potential to produce purer, less expensive cellulose and lignin fractions as starting materials for such products as:

- Cellulose for dissolving pulp;
- Cellulose esters used in coatings, thermoplastics, and textiles;
- Cellulose ethers used in latex paints, industrial thickeners, and food additives; and
- Lignin for quinones used in polymer intermediates, dyes, and pulping catalysts (see special article on pulping catalysts from lignin).

Industry is currently evaluating the laboratory samples, and the next step depends on their findings. Possible outcomes includes a collaborative partnership to further evaluate the derived products, a scale-up effort with an industrial partner, or both. A decision is expected soon after the first of the year. [Bob Armstrong, (202) 401-4860; Harry Parker, (806) 742-3553; William Tallent, (301) 504-6786; and Gloria Kulesa, (202) 586-8091]

Modest U.S. Economic Growth in 1995 Provides Support for Industries Using Agricultural Materials

The U.S. Gross Domestic Product and industrial production are expected to grow 3.9 and 5.6 percent, respectively, in 1994. Growth, however, is forecast to slow in 1995. Inflation is expected to be 3.4 percent in 1995, up from an anticipated 2.7 percent in 1994. Industrial markets for agricultural products should continue to grow, albeit more slowly.

The consensus of private forecasters is that the U.S. Gross Domestic Product (GDP) will grow by 2.9 percent in 1995. Industrial production is expected to be up between 4 and 4.5 percent, along with strong export and investment growth. Analysts forecast housing starts to decline and consumer-durable growth to slow, dampening advances in both GDP and industrial production. Housing starts are expected to decrease from a likely 1.42 million units in 1994 to 1.36 million units in 1995.

In addition to a decline in residential construction, most forecasters expect weak plant investment in 1995, reducing overall construction for the year. Some analysts, however, pointing to high use of factory capacity, expect substantial growth in plant construction that will offset the expected decline in housing starts, making 1995 a growth year for the construction industry in most areas of the country. Most analysts expect strong business-equipment spending because profits have been increasing and are expected to continue rising in 1995.

Consumer prices are expected to rise 3.4 percent in 1995. Given this anticipated inflation and continued strength in industrial production, the Federal Reserve Board (Fed) is expected to put more upward pressure on short-term interest rates to restrain GDP growth to the 2.5- to 2.7-percent range.

Economic Growth Was Strong in Third Quarter

In the third quarter of 1994, growth was initially estimated at 3.9 percent, higher than most analysts expected. Strong growth in consumer durable goods, exports (at an annualized rate of 12.2 percent), and government spending, along with substantial gains in business-equipment spending, led to the high rate. Increased consumer disposable income, especially from wages, combined with readily available bank loans (albeit at higher interest rates), fueled the demand for consumer durables and business equipment. Although real (adjusted for inflation) car and truck spending was flat for the quarter, durables grew at an annualized rate of 6.3 percent because of strong furniture and appliance sales. Nonfarm business inventories, which were expected to drop, grew by some $6 billion.

Imports rose at an annualized rate of 15.6 percent during the third quarter, increasing the real trade deficit. Spending on business construction rose slowly at an annualized rate of 1.1 percent and residential investment fell at an annualized rate of 3.9 percent. Oil prices stabilized and spending on nondurable consumer goods increased 8.9 percent during the quarter.

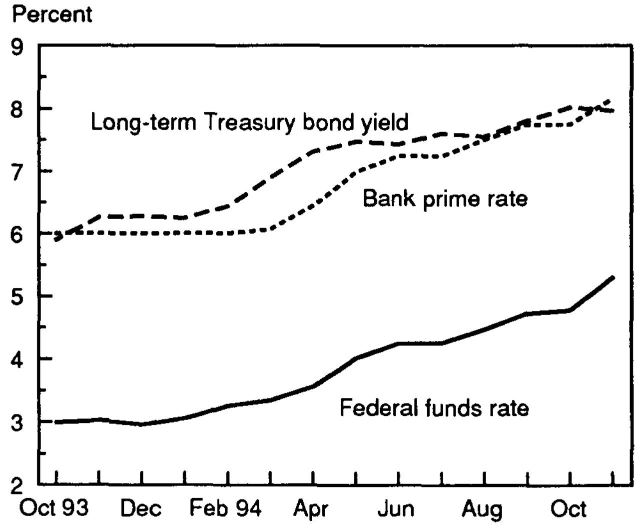
Interest Rates and Employment Increase

Since the economy was on a solid recovery path in early 1994, the Fed decided to institute a neutral monetary policy to prevent a resurgence of inflation. As a result, the Federal funds rate (the rate which banks charge each other for loans to cover reserve requirements) increased six times in 1994 from 3 percent in January to 5.6 percent in early December. Other rates went up (figure 1), reflecting the rise in the Federal funds rate, expected future tightenings, and increases in credit demand as our major trading partners recover. Most analysts expect the Fed to push up interest rates again next year.

Because of these interest rate hikes, GDP growth was slightly slower than it would have been otherwise in the third quarter of 1994. But the economy and the industrial

Figure 1

Interest Rates Have Risen Throughout 1994



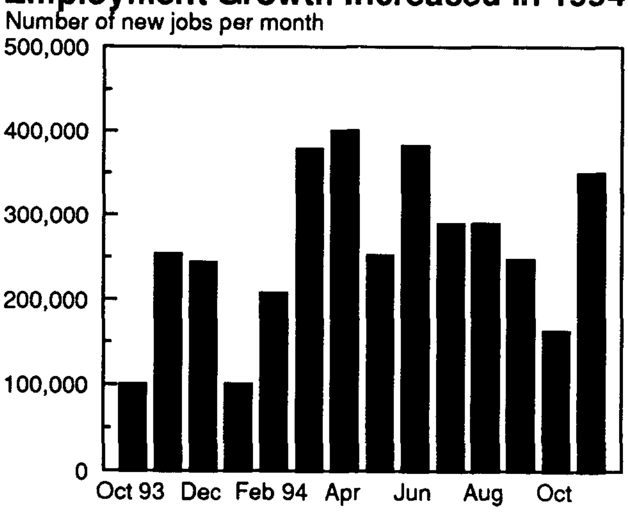
sectors have been surprisingly resilient. Overall GDP growth for 1994 is expected to be 3.9 percent. The year is likely to be as strong as any since 1988. The economic strength was driven by productivity growth, providing very strong employment growth and some modest wage increases. Industrial production for the year grew at about 5.8 percent. Despite higher interest rates, most interest-sensitive sectors, including housing and furniture that rely on forest products and textile production, were profitable and grew during 1994. Home sales fluctuated more from quarter to quarter than other interest-sensitive sectors, but are expected to be higher in 1994 than in 1993. Housing starts are anticipated to be about 1.42 million, up from 1.29 million in 1993, an increase of 10.1 percent.

Employment grew an average of nearly 279,000 per month for the first 11 months of 1994, including an unexpectedly large increase of 350,000 in November (figure 2). The manufacturing sector added 50,000 new employees in November, also higher than expected. Except for California, every region is in recovery. Some areas of the Midwest recently reported bottlenecks in the labor market with wage increases above inflation. Overall labor markets appear to have substantial slack, which, coupled with higher productivity growth, likely will restrain 1994 inflation to 2.7 percent. Unemployment is expected to average about 6.4 percent for 1994.

Refined crude oil prices rose this year from $13 per barrel in January to $16 by the end of October, with a run up in the middle of the year to almost $18. Prices for gasoline and diesel fuel are expected to rise at the end of the year, reflecting the carbon monoxide provisions of the Clear Air Act. The U.S. Department of Energy's Energy Information Administration and most other analysts expect higher crude oil prices in 1995, reaching $18 per barrel by next fall. The forecast is based on expected growth in developed countries, which will increase demand with no great shift in supply.

Figure 2

Employment Growth Increased in 1994



Manufacturing Use of Agricultural Products Will Grow More Slowly in 1995

With GDP expected to grow 2.7 percent in 1995, industrial markets for agricultural products should continue to grow, albeit more slowly than in 1994. Although net exports are expected to drop in 1994, the growth in exports of manufactured goods will likely reach double digits. Modest increases in agricultural exports are expected next year, which will likely generate more demand for food and kindred products and industrial products that use agricultural materials. The expected rise in investment and personal spending should bring further growth in manufacturing sectors: furniture, plastics and rubber, corn milling and oilseed crushing, textiles, and leather-related products.

Production of fabricated metal products is important to industrial rapeseed and crambe oils, which are used as raw materials for lubricants in rolling and stamping metal products. Given the good outlook for industrial production in 1995, use of fabricated metal products is expected to expand. Domestic textile production, which has been robust in 1994 compared with 1993, will likely remain strong. Growth in printing and publishing expected for next year will raise the demand for paper and petroleum and vegetable-oil inks.

Even an increase in the demand for food and kindred products will (with some lag time) expand industrial uses of agricultural materials. For example, higher demand for meat products in 1995 would increase input use of fats and oils; paper and allied products; chemicals and selected chemical products; plastic and synthetic materials; and transportation, communication, and utility services. More specifically, a $1 increase in the final demand for meat products would require, directly and indirectly, 11 cents worth of fat and oil products and 20 cents worth of other manufactured products, such as paper, chemicals, and plastics. Use of transportation services would increase 8 cents, personal and business services would rise by 17 cents, and the wholesale and retail trade sector would generate an additional 12 cents of business activity.

Because of the expected slowdown in residential construction, wood and lumber use will likely decline. The residential construction industry uses 21 percent of the output from the nation's saw and planing mills. These mills used 89 percent of the timber harvested in 1987. If, as some analysts suggest, plant investment grows enough to offset the expected decline in residential housing starts, lumber and wood product demand could still grow in 1995. [David Torgerson, (202) 501-8329; and Chin Lee, (202) 501-8340]

Ethanol, Starch, and Sorbitol Increase the Demand for Corn

Despite the Court stay on the U.S. Environmental Protection Agency's renewable oxygenate requirement, high methanol prices and a recent Treasury Department announcement that ETBE is eligible for excise tax exemption could push ethanol production close to 1.5 billion gallons in 1995. Industrial uses of corn are forecast to reach 748 million bushels in 1994/95, up 12 percent from 1993/94. Cornstarch is used to make sorbitol, a polyol widely used in personal-care products.

Ethanol Had a Busy Year in 1994

The year began with ethanol supporters, oil companies, agricultural interests, and the U.S. Environmental Protection Agency (EPA) continuing their debate over what role ethanol will play in the Clean Air Act's reformulated gasoline (RFG) program. EPA had announced their decision in December 1993 to require 30 percent of the oxygen in RFG be derived from renewable sources. This "renewable oxygenate requirement" (ROR) would guarantee ethanol a role in the RFG program.

On January 14, 1994, EPA held a public hearing on the ROR and testimony was given by witnesses representing oil companies, agricultural interests, environmental groups, state regulatory agencies, and public interest groups. This hearing was followed by a 30-day comment period during which written comments and other documents were placed in the official record.

USDA submitted comments indicating strong support for the Administration's decision and pointing out the many benefits this rule would have on U.S. agriculture. USDA estimated full implementation of the ROR would increase net ethanol demand by 500 million gallons annually. This increase would account for an additional 200 million bushels of corn use. Added to the 1.25 billion gallons of production expected in 1994, ethanol production would increase to more than 1.7 billion gallons by crop year 1997/98.

EPA issued a final ROR regulation on June 30, 1994, which would require 15 percent renewable oxygen in RFG during 1995 and 30 percent thereafter. However, on July 13, 1994, the American Petroleum Institute and the National Petroleum Refiners Association filed suit in the U.S. Court of Appeals for the District of Columbia asking the Court to overrule EPA and find the ROR illegal. While many expected this challenge by the oil industry, ROR supporters are pleased with the aggressive response EPA has made toward this suit.

On September 13, 1994, the Appeals Court ordered EPA to stay its implementation of ROR. The Court also ordered a quick review of the case so that it can be resolved before the RFG program has been in effect a long time. The Court order lays out a schedule for EPA, the oil industry, and the Renewable Fuels Association to file legal briefs with the Court. The last set of briefs is due January 12, 1995, and oral arguments likely will begin shortly thereafter. A final decision is expected in the spring.

The RFG program will begin on January 1, 1995, in all areas that are mandated or have opted into the program. Annual demand for RFG is expected to be about 36 billion gallons, all of which must contain at least 2.0-percent oxygen by weight. Oxygen can be added to gasoline in the form of alcohols or ethers made from alcohols. Currently, there are three oxygenates that are expected to be widely used in RFG: ethanol, ethyl tertiary butyl ether (ETBE) made from ethanol, and methyl tertiary butyl ether (MTBE) made from methanol.

All three can be used to produce RFG, but ethers like ETBE and MTBE have some advantages over ethanol. First, RFG made with ethers can be shipped in pipelines; ethanol blends cannot because they attract water. Second, ethanol increases the evaporation rate of gasoline. For this reason, ethanol cannot be mixed with other RFG fuels because the evaporative emissions contribute to smog formation. ETBE, however, does not increase evaporation; in fact, it reduces evaporation significantly. A common misunderstanding about ETBE is that it uses less ethanol to make a gallon of RFG. This is not true. The oxygen in ETBE comes from ethanol. Therefore, to make a gallon of RFG using ETBE, just as much ethanol is needed for ETBE as would be needed for blending ethanol directly into the fuel.

With the Court stay in place, many have wondered what the future holds for the ethanol industry. Difficulties associated with using ethanol in RFG, because of mixing and blending restrictions, were thought to put ethanol at a disadvantage in RFG markets. ETBE has been more expensive than MTBE because methanol has been cheaper than ethanol and it contains less oxygen than methanol. A recent market development that could promote the use of ethanol, regardless of the Court's ruling, has been the rapid increase in methanol prices over the past year.

Methanol is made mostly from natural gas. Methanol is not only used as fuel and a feedstock for MTBE, but also in chemical applications. For example, methanol is a feedstock for the resins and adhesives used in making plywood and other building materials. Greater economic activity and the upcoming RFG program have caused an increase in methanol demand that has pushed prices up to $1.40 per gallon from 35 cents just a year ago. The recent temporary closing of a large U.S. methanol plant due to an explosion has increased the tightness in methanol markets, and prices in mid-October reached $1.80 per gallon. Industry experts are now predicting these tight market conditions may persist until additional plant capacity comes on line in 1996.

In addition, the Treasury Department announced on October 17, 1994, that the ethanol portion of ETBE will be eligible for the same excise tax exemption now available to ethanol and other qualifying alcohols. This ruling will remove significant economic barriers to ETBE commercialization in the RFG market.

While the ROR Court stay could have negative effects on ethanol use, rising methanol and MTBE prices and the recent Treasury tax ruling have created positive economic opportunities for ethanol and ETBE in the RFG market. Many refiners are talking about using ethanol, ETBE, or both in their RFG around the country. If the market situation continues with high methanol prices, this could be enough to maintain ethanol-industry growth at levels USDA predicted earlier this year (see June 1994 issue of this report). Ethanol production is expected to be about 1.25 billion gallons in 1994 and could approach 1.5 billion gallons next year.

More Corn Needed for Ethanol and Starch in 1994/95

Industrial uses of corn are forecast to reach 748 million bushels in 1994/95, up 12 percent from 1993/94 (table 1). Most of the increase is expected to be used to produce ethanol. In 1994/95, industrial demand is expected to account for 8 percent of total corn use, down from 9 percent in 1993/94.

Starch production in 1993/94 used 2 percent more corn than the year before. Growth in the economy helped increase starch use, which was essentially unchanged during marketing years 1991/92-1992/93. The U.S. economy will likely expand 2.9 percent in 1995, thus starch production is expected to continue to rise. In 1994/95, starch production for industrial purposes is anticipated to require 3 percent more corn than the 207 million bushels needed in 1993/94. A lot of starch is used in paper products, and as the economy grows, more shipping boxes and other types of paper are needed. Also, greater use of recycled paper has helped boost starch use because the shorter wood fibers need extra bonding.

With the decrease in corn prices in July 1994, starch wholesale prices declined in August but still stayed slightly above year earlier levels. Prices for starch are generally negotiated between buyer and seller and depend upon size of purchase, amount of modification done to the starch, and competition among sellers. Many starch users have shifted from buying unmodified starch to buying modified starch that has the particular properties they need in their manufacturing process. Producers are now researching user needs and supplying different types of modified starch to their customers. With the large corn crop harvested in 1994, processing supplies will be lower priced than in 1993/94, but the stronger demand for starch will likely keep starch prices from reflecting the full decline in corn prices.

Sorbitol Production Uses Cornstarch as a Feedstock

Sorbitol is a six-carbon polyol made by catalytic hydrogenation of sugars, using either batch or continuous-flow processes. Most sorbitol produced today is from dextrose sugars derived from cornstarch. It is available commercially in food and industrial grades, and is sold in powdered, granular, or liquid form.

There are seven producers of sorbitol in the United States: Archer Daniels Midland Company; ICI Americas; Pfizer, Inc.; Lonze, Inc.; Hoffmann-LaRoche; Ethichem Corporation; and Roquette Corporation. They have a

Table 1--Industrial uses of corn, 1990/91-1994/95

Marketing year 1/	HFCS 2/	Glucose and dextrose 2/	Starch: Food uses	Starch: Industrial uses	Starch: Total 3/	Fuel alcohol	Total industrial use 4/
			Million bushels				
1990/91	379	200	35	197	232	349	546
1991/92	392	210	36	202	237	398	600
1992/93	414	215	36	202	238	426	628
1993/94	442	223	37	207	244	458	665
1994/95 5/	455	225	38	213	250	535	748

1/ Marketing year begins September 1. 2/ High fructose corn syrup (HFCS), glucose, and dextrose are primarily used in edible applications, such as food and health-care products. 3/ Industry estimates allocate 85 percent of total starch use to industrial applications and 15 percent to food applications. 4/ Industrial uses of starch and fuel alcohol. 5/ Forecast.

combined capacity of 527 million pounds. In 1992, 408 million pounds of sorbitol was produced and consumed in this country, utilizing roughly 25 million bushels of corn.

Four major market segments account for most of sorbitol use: personal-care products, food applications, surfactants, and vitamin C (figure 3). Plastics, specialty plasticizers, and pharmaceuticals make up the remaining 10 percent. The U.S. Food and Drug Administration has approved sorbitol for use in foods, cosmetics, and pharmaceuticals.

Within the personal-care segment, sorbitol is used in toothpastes, cosmetics, and toiletries. The toothpaste industry is a significant consumer, where sorbitol is used as a humidity control agent and delivery vehicle. Sorbitol's use in toothpaste grew rapidly in the 1970's when gel toothpastes became popular. Gel toothpastes contain up to 50-percent liquid sorbitol, which is twice the amount in paste toothpastes.

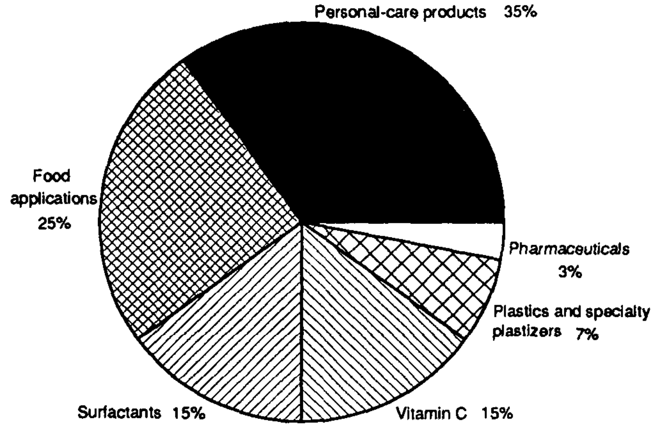
Sorbitol's main competitor at the time for the toothpaste market was glycerol (a 3-carbon alcohol commercially known as glycerine), which had been used in toothpastes for some time. Although about 10 percent higher in price, sorbitol was viewed with favor because it was a natural product. In the 1970's, about 70 percent of glycerol was petrochemically derived. By the middle of the 1980's, two-thirds of glycerol was derived from natural sources and there was no difference between the nature and quality of sorbitol and glycerol. By then, however, the markets for sorbitol were established and production costs were below those for glycerol. In the 1990's, sorbitol has made further inroads into glycerol's markets in the personal-care industry. Colgate regular toothpaste is now the only toothpaste on the market that contains only glycerol. Currently, sorbitol is priced at 33 cents per pound, while glycerol is $1.07 per pound.

Sorbitol also is used in mouthwashes, imparting a cooling sweet taste. The cosmetic industry uses sorbitol as a humidity control agent and as a gel base. Because sorbitol is hygroscopic (it absorbs moisture from the air), it also serves as an emollient in creams and lotions.

Sorbitol is used in foods as a sweetener; it is 60 percent as sweet as sucrose. Since sorbitol is resistant to tooth-decay bacteria, it is increasingly used in many "sugarless" products, such as sugarless gums and candies. Sorbitol also is used as bulking and flavoring agents. A more recent application is as a cryoprotectant (to maintain the structural integrity of frozen foods).

Figure 3

U.S. Uses of Sorbitol in 1992 1/



1/ Production and use in 1992 was 408 million pounds.
Source: Irshad Ahmed; Booz, Allen & Hamilton, Inc.; Bethesda, MD; October 1994.

Vitamin C (ascorbic acid) production consumes about 15 percent of sorbitol supply. Before sorbitol was used to make Vitamin C, most of it was produced from petrochemical sources, with a small percentage extracted from natural citrus sources.

Sorbitol is esterified to produce a wide range of surfactants and related surface-active products. The major uses of sorbitol derivatives are as lubricant additives, softeners in textile manufacturing, plasticizers, antifog agents, antistatic agents, and components in dry cleaning fluids. Sorbitol-based surfactants are also used in food processing, cosmetics, and pharmaceuticals.

Sorbitol is being used to manufacture plastics and specialty plasticizers. For example, various polyethers are made from sorbitol. It is also used in the manufacture of polyol components of polyurethane resins and foams. Sorbitol has additional uses in the pharmaceutical industry as a stabilizer or sweetening agent for a number of drugs, like cough syrup. [John McClelland, (202) 501-6631; Irshad Ahmed, (301) 951-2060; and Allen Baker, (202) 219-0839]

Meadowfoam Oil and Polyols Expand Vegetable Oil Markets

Meadowfoam, a new oilseed crop grown in Oregon, contains a unique oil that is used in cosmetics and has potential in other applications. Recent plant breeding, agronomic research, and oil-product development are bringing meadowfoam closer to commercial viability. Polyols, which are traditionally derived from petrochemicals, are now being made from vegetable oils.

Meadowfoam Is Commercially Produced in Oregon

Meadowfoam is a low-growing winter annual native to the Pacific Northwest. Seeds collected from wild stands were tested in the late 1950's as part of a USDA-initiated search for plants that could provide industrial raw materials. Research in the early 1960's indicated that the Willamette Valley of Oregon would be a good area for meadowfoam production. In 1967, Oregon State University initiated a crop improvement and agricultural production program for meadowfoam. This program was expanded in 1980 as a result of funding from the Oregon grass-seed industry, which was searching for alternative crops for the poorly drained soils of the Willamette Valley and a way to lessen the pollution resulting from the field burning required after harvesting grass seed. Legislation adopted in 1991 reduces the acreage that may be open-burned from 250,000 to 65,000 in 1998.

Meadowfoam is an oilseed crop planted in the fall and harvested in early summer. Equipment and cultural practices are similar to those used for winter grain and seed crops. Meadowfoam requires insect pollination; honey bees have been the primary pollinator used by farmers and researchers. At maturity, plants are 10 to 18 inches tall. Commercial production began in 1984 with 600 acres planted by the 24 members of the Oregon Meadowfoam Growers Association. Since then, acreage has fluctuated from 0 to 1,000. This fall, 2,200 acres were planted. Yields have varied dramatically, from 600 to 1,300 pounds per acre. The major factors involved in yield variation have not all been identified, but differing levels of insect pollination appears to be part of the cause.

The small seeds average about 30 percent oil. Meadowfoam oil consists primarily of long-chain fatty acids. More than 95 percent are 20 carbons or longer, which is unique among commercial vegetable oils (table 2). Most of the fatty acids also contain one or two double bonds, which are referred to as monounsaturated or polyunsaturated, respectively. This composition imparts considerable oxidative stability, which is required in cosmetics and is potentially useful in lubricants. Another special feature of meadowfoam's dominant fatty acids is the location of the double bond at the unusual delta-5 position. This allows chemists to make products that cannot be derived from other vegetable oils.

The first commercial sale of meadowfoam oil was made in 1985 to a Japanese firm for use in cosmetics, and the Japanese cosmetic industry remains the major purchaser. In 1993, the Oregon Meadowfoam Growers Association signed a contract with Chicago-based Fanning Corporation, which sells lanolin and other products to the cosmetic and pharmaceutical industries, to market the oil. Skin-care products are currently the oil's primary use.

To explore additional uses, a number of meadowfoam oil derivatives have been made in the laboratory by scientists at USDA's National Center for Agricultural Utilization Research (NCAUR). For example, meadowfoam oils has been vulcanized (reacted with sulfur or sulfur mono-

Table 2--Typical compositions of meadowfoam, rapeseed, crambe, and soybean oils

Fatty acid name and formula 1/	Meadowfoam oil	Rapeseed oil	Crambe oil	Soybean oil
		Percent		
Less than C18	0.5	2.5	2.3	10
Stearic (18:0)	--	1	1	4
Oleic (18:1)	1.4	14.5	16	22
Linoleic (18:2)	0.5	15.2	9	54
Linolenic (18:3)	--	10	6	7.2
Eicosanoic (20:0)	0.5	0.6	1	--
cis-5-eicosenoic (5-20:1)	64	--	--	--
cis-11-eicosenoic (11-20:1)	0.2	9.5	3.5	--
cis-5-docosenoic (5-22:1)	3	--	--	--
Erucic (13-22:1)	10	43	55	--
cis-5, cis-13-docosadienoic (5,13-22:2)	19	--	--	--

-- = Not present in significant amounts.

1/ The formula indicates the location of the double bonds, chain length, and number of double bonds.

Source: S.M. Erhan and R. Kleiman, "Vulcanized Meadowfoam Oil," Journal of the American Oil Chemists' Society, Vol. 67, No. 10, October 1990, pp. 671.

chloride) to produce compounds used in rubber formulations. The vulcanized oil, which is called "factice," had properties equivalent to or better than high-quality, rapeseed-oil factice. However, factices are also made from soybean, castor, and other vegetable oils. Meadowfoam factice would have to be cost competitive to enter this market.

Meadowfoam oil has been epoxidized (adding an oxygen atom across a double bond). The resulting derivatives could be used in coatings, polymers, and lubricants and as plasticizer-stabilizers. Some plasticizers currently are made from vegetable oils, primarily soybean oil (see the June 1994 issue of this report). Meadowfoam oil also can be hydrogenated to produce a wax similar to carnauba and candelilla waxes, but a significant market for these materials has not yet developed.

Dimer acids and esters have been made using meadowfoam oil. The meadowfoam compounds were comparable to commercial products, which are used in adhesives, corrosion inhibitors, lubricants, and lubricant additives. Meadowfoam fatty amides have been prepared and purified, which could be used as slip and antiblock agents in polyethylene films.

Meadowfoam's fatty acids have also been used to make estolides, which have potential uses in lubricants, plasticizers, cosmetics, and printing inks. Traditionally, estolides are formed by esterifying the double bond in an unsaturated fatty acid to the hydroxyl group of a hydroxy fatty acid, thus linking the two fatty acids together. However, a new procedure developed by NCAUR chemists produces estolides directly from monounsaturated fatty acids. The reaction has a particularly high yield when using meadowfoam oil because of its high concentration of monounsaturated fatty acids. A patent has been allowed for this process, and it will be granted in mid-January. Patents are pending on other products based on the chemistry of the delta-5 double bond.

The meal remaining after the oil is extracted contains 21 percent crude protein and 27 percent acid detergent fiber. The amino acid profile of meadowfoam meal closely resembles those of industrial rapeseed and crambe meals. It has been evaluated as a feed for chickens, rabbits, sheep, goats, and beef cattle. Because of the glucosinolates present in the meal, nonruminant animals gained less weight than with a standard ration. However, lambs and beef cattle responded satisfactorily when fed meadowfoam meal.

According to David Nelson, executive secretary of the growers association, commercial development of meadowfoam has been a break-even proposition for the growers thus far. However, meadowfoam is becoming an important crop for grass-seed growers, enabling them to clean up fields infected with grassy-type weeds. A informal consortium has come together to further commercialize meadowfoam and its products. Participants include the Oregon Meadowfoam Growers Association, Fanning Corporation, Oregon State University, and NCAUR. Plant breeding, agronomic research, and oil-product development is progressing rapidly--bringing meadowfoam closer to commercial viability.

Vegetable-Oil-Based Polyols Hit the Market

Polyol is the basic compound used in the production of polyurethane and several other classes of plastic products. Traditionally derived from petrochemicals, polyol is now being made from vegetable oils. For example, Natural Resources Group, a British research company, operates eight vegetable-oil-based polyol plants throughout the world. The company has two plants in Canada, two in northern China, and one each in northern India, Zimbabwe, the United Arab Emirates, and Poland.

Biobased polyol production can utilize a variety of raw material sources--both virgin and waste vegetable oils. The list includes canola, castor, peanut, sunflowerseed, olive, cottonseed, palm kernel, coconut, and fish oils. This raw material flexibility not only protects against feedstock shortages, it also makes polyol production suitable for developing countries that produce surplus quantities of vegetable oils.

Not only can vegetable-oil-derived polyol be used in the manufacture of polyurethane and related products, it also has exceptional blending properties. To date, biobased polyols have been tested as inputs in the production of foams, elastomers, marine coatings, adhesives, polymer concretes, and housing components. Polyol could be a useful feedstock in developing new end-product applications, as well as producing environmentally improved versions of existing products, such as electrical cord coatings and nontoxic fire retardant foams.

Currently, vegetable-oil-based polyol is being produced in small-scale plants in multiple batches of 4 tons each. Such small-scale facilities allow producers to adapt to seasonal feedstock changes and to minimize capital costs. Ecotek Holdings, Ltd., of Lions Bay, British Columbia, has constructed a standard size polyol plant on a 40-foot truck that is capable of processing any vegetable oil into polyol. It also is equipped with a quality control laboratory.

International Polyol Chemicals, Inc., of Redmond, WA, has develop a patented new technology for turning cornstarch into polyols, such as propylene glycol, glycerine, and ethylene glycol. The company currently processes 5,000 tons of cornstarch per year in a pilot-scale facility. Plans are underway to develop a commercial-scale plant, with the goal of processing

100,000 tons per year. USDA's Alternative Agricultural Research and Commercialization Center invested $300,000 in the venture to support additional research. The U.S. Department of Energy's Alternative Feedstocks Program also contributed $300,000 to help transfer expertise in catalysis operations from Pacific Northwest Laboratory to the company.

Polyol from canola oil and polymerized with fuel ash from coal-fired power stations is being used to produce polyconcrete, a construction material produced in different strengths for applications ranging from construction-grade building blocks to household appliance shells. This process has two environmental benefits. First, it replaces nonrenewable fossil fuel feedstocks with renewable vegetable oil. Second, it utilizes fuel ash that is otherwise dumped in a landfill or at sea.

According to industry sources, production costs for vegetable-oil-based polyol average 15- to 20-percent higher than for polyol made from petrochemicals. However, the manufacturing process for vegetable-oil-based polyol is more environmentally friendly than comparable petroleum-based processes and such benefits may compensate for some of the cost differential. Furthermore, production costs could decrease in the future as the technology improves. Currently, a gallon of high-grade polyol derived from vegetable oil costs $15 a gallon.

Production costs also differ depending on the end product. For example, vegetable-oil-based polyol used to coat electrical cords is 10 to 15 percent cheaper than electrical-cord coatings derived from petrochemical feedstocks. In comparison, biobased polyol used to produce fire-retardant foams tends to cost 15 to 20 percent more than similar products made from fossil fuels. However, most of the current fire-retardant foams are petroleum derived and based on toluene 2,4-diisocyanate (TDI), which is a carcinogen. When these foams are sprayed on high-temperature fires, they produce toxic fumes. Fire-retardant foams made from vegetable-oil-derived polyol can replace TDI-based foams. The biobased-polyol foams emit harmless water vapors when applied to high-temperature flames. [Lewrene Glaser, (202) 219-0091; Irshad Ahmed, (301) 951-2060, and Harry Parker, (806) 742-3553]

Use of Composite Products Is Growing

Composite products are an important and growing segment of the forest products industry. Over 70 percent of all wood materials in use today contain some type of adhesive, and that figure is expected to grow as new products and processes are developed. As supplies of virgin timber tighten, nonwood biomass fibers, such as straw, and recycled fiber products, such as paper and wood wastes, are being used as raw materials for composite products.

Composite products are an important and growing segment of the forest products industry. In the last 50 years, solid-sawn lumber and timber construction have given way to advances in composite technology. Within the industry, the term composite is usually used to describe any wood product that is glued together. Over 70 percent of all wood materials in use today contain some type of adhesive, and that figure is expected to grow as new products and processes are developed. Composites offer superior performance, reduced weight and volume, cost effectiveness, fatigue and chemical resistance, and controlled biodegradability. In addition to wood, materials such as plastics, glass, metal, synthetic fibers, and other biomass materials can be used to make composite products.

The timber products industry has evolved to utilize timber resources that are available. As the quality of timber resources has declined, new methods for processing and reconstituting forest products have been developed. This trend is expected to continue as future harvests from Federal lands will remain low due to environmental concerns. The forest products industry is conducting research in cooperation with USDA's Forest Products Laboratory and universities to develop new processes and materials to extend timber supplies and promote energy efficiency.

Composite Evolution Began in the 1950's

The original composite-panel product was plywood, which became popular in the 1950's with the development of phenolic adhesives. Plywood became a superior replacement for 1-inch-sheathing lumber used in housing frames. In the 1970's, the waferboard industry emerged, principally in Canada, using mainly aspen flakes glued together under pressure. In the 1980's, a refinement of this process was developed that cuts logs into long strands parallel to the grain, which are then oriented and blended with adhesives to produce a board with the outside layers oriented parallel to the grain and the center core with the short dimension. The panel is then pressed and cured. The resulting oriented-strand board (OSB) is similar to plywood in its applications. OSB generally costs slightly less than plywood, about 30 cents per square foot, and conserves wood use.

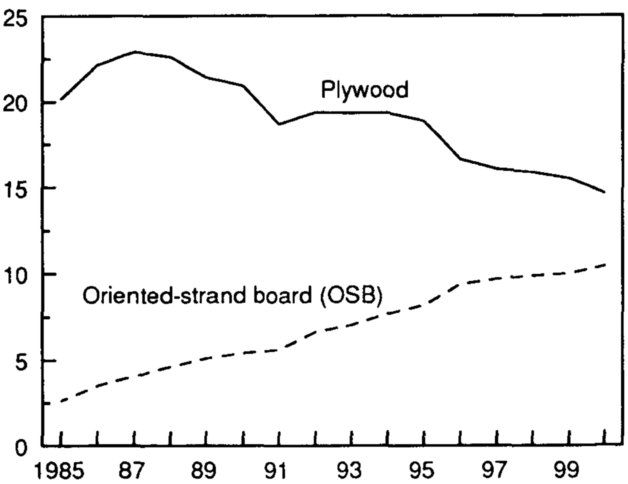
OSB production has been growing steadily in the United States since its inception. Production increased from 2.7 million square feet (3/8-inch basis) in 1985 to about 7.1 million in 1993. If present trends continue, OSB production in the United States will rise to 10.4 million square feet in 2000 (figure 4). Plywood production was about 20 million square feet (3/8-inch basis) in 1985 and then rose to about 22 million square feet in the late 1980's. In the 1990's, however, OSB displaced plywood in many uses, especially sheathing. Plywood production declined to 19.3 million square feet in 1993 and is projected to go down to about 14.7 million square feet by 2000.

Composite panel products can also be produced from nonwood biomass materials, waste wood, or wastepaper. Straw from wheat or barley has been proposed as a raw material for making particleboard that could be used as a building material. Agricultural fiberboards have been found to offer superior strength, heat and sound insulation, and resistance to fire due to their density compared to standard 2-by-4-inch lumber and sheetrock wall systems.

Figure 4

OSB and Plywood Use in the United States

Million square feet, 3/8-inch basis



1/ 1995-2000 projected.

Source: American Plywood Association.

A large-scale plant using up to 340,000 tons of straw annually has been proposed for North Dakota by Isobord Enterprises, Inc., of Toronto, Ontario, to produce a fiber-composite board. Another straw fiberboard plant is proposed for Montana using an established English system to compress straw into fiberboards. Other agricultural biomass projects are under consideration in Iowa, Kansas, Oregon, and other states.

Enviroboard is a product similar to OSB that uses 75- to 90-percent cereal straw combined with cement and adhesives. Made by Home Builders International, it is being used to build homes in South Dakota, Minnesota, and Wisconsin. Also, in Minnesota, Phenix Composite, Inc., is commercializing a new composite product called Environ, made of soybean monolithic resin and waste paper. According to the company, the material looks like granite but has the construction properties of wood. It can be manufactured into panels, blocks, or veneers and colored to simulate many granite hues.

New Technologies and Recycling Mean New Wood-Conserving Composites

Of the approximately 195 million tons of solid waste generated in the United States in 1990, about 40 percent was paper, 10 percent plastics, and 8 percent wood waste. While data are available for certain wood-based products in municipal solid waste, information is incomplete for timber thinnings, industrial production wastes, and sawdust. In 1992, 540 million pallets were produced. Many will be reused, but all will eventually require disposal.

Fiber-based waste products--such as paper, yard wastes, and solid-wood wastes--can be readily reduced to a particulate or fiber form suitable for composites. The potential exists for recycled wood fibers and plastics to produce a wide spectrum of products ranging from very inexpensive, low-performance composites to expensive, high-performance materials. New fiber technology, bonding performance, and fiber modification can be used to manufacture wood-plastic composites with uniform densities, durability, and high strength.

An existing, though not widely used, building product that can readily be adapted to use recycled wood material utilizes an inorganic binder, such as portland cement. Inorganic-bonded wood panels made with virgin untreated wood have very good strength properties, as well as excellent resistance to fire, fungi, and termites. This type of panel is being used in construction in Europe, Asia, and South America.

A cement-bonded product may be an efficient way to utilize preservative-treated recycled materials. Many end uses are predicated on good performance in harsh environments and because the product has a long-life expectancy, it can tie up the preservatives for relatively long periods of time. Considering that over 60 percent of all the southern pine lumber cut today is treated with some sort of preservative, the presence of this material in the waste stream will likely increase.

Several specific technologies exist that have the potential for producing housing products from recycled wood waste. Technologies with the greatest potential for success include: Dry-formed reconstituted wood products from fibers, flakes, chips, or particles; wet-formed wood products from fibers; wood/plastic combinations; wood/cement combinations; reuse of old lumber from razed buildings; and remanufacture of lumber from short-piece wood wastes from construction sites. A significant advantage of utilizing recycled wood waste is the opportunity to depart from conventional framing and panel building systems.

"Reconstituted" describes a process where wood-waste materials are broken into small pieces and reassembled into new forms with the aid of an adhesive. Because the raw materials are from waste, recyclable wood comes in many different forms from many different sources. This poses special processing considerations. These include size reduction and necessary cleaning operations. Blending the wood pieces will reduce performance variations caused by species differences. Much of the technology currently used for manufacture of fiber- and particle-based wood products using virgin wood is transferable to recyclable wood. Commercially, wood fibers are used in all manner of fiberboard and can be molded into a variety of geometric shapes. One readily identifiable product made using this technology is interior door panels for automobiles.

Wood waste has the potential for use in wood-flake products as well. However, making wood flakes from recyclable wood may be the most difficult of all the technologies mentioned here. Therefore, flake technology will probably be most useful where the waste stream is very tightly controlled. The raw material should be softwood flakes with a high-moisture content and must be properly pre-sized to produce a consistent product. Flakes are commonly used to produce sheathing products, such as OSB. Flakeboards are also used as one or both skins in stressed-skin panels and for webs in wood I-beams.

Another process with potential for utilizing solid wood wastes, including lumber scraps and tree trimmings, involves crushing the wood into splinters. This process offers attractive advantages over other wood-reduction techniques since no cutting is required. Because they have high length-to-cross-section ratios, splinters are strong and can be highly oriented. Dry hardwoods splinter exceptionally well, so this technology seems like a natural outlet for used hardwood pallets. This splintering process has shown potential in Australia, where a structural wood product called "scrimber" has been developed.

Research is currently underway at USDA's Forest Products Laboratory to produce both structural and nonstructural housing components from recycled wastepaper fiber. Using a three-dimensional pulp molding process, a structural housing component, spaceboard, is formed by draining a pulp slurry through a resilient mold. The mold is then hot-pressed to densify and dry the product. A preliminary study has demonstrated the potential of spaceboard as a floor panel product. This process can readily accept recycled wood fibers and has the potential for both curvilinear and three-dimensional solid formed products. This molding potential will greatly enhance the flexibility architects and engineers have in designing housing.

Another potential technology to use recycled wood fiber is a pulp extrusion process. A pulp slurry is dewatered, densified, and dried as it is forced through special dies. This prooess has the potential to produce products with various dimensions and cross sections, with essentially unlimited length. Potential products might include casing and trim products and lumber-type profiles.

A third type of wet-formed, fiber-based process involves shaping structural components through the winding of paper-sheet stock. This process incorporates existing sheet-forming technology, but has the potential to utilize recycled paper stock. A number of potential housing components can be produced this way, since many shapes can be formed.

All three of these technologies have potential to produce structural housing components, including studs and wall corner posts, interior and exterior sheathing, as well as beams and floor panels. Nonstructural (nonload bearing) elements are also possible. Gridcore Systems International of Carlsbad, CA, has licensed the spaceboard technology from USDA and is using it to manufacture Gridcore panels. The panels--which are made from recycled corrugated containers, newspapers, and wood waste--are used in furniture, movie sets, and stage displays. The company plans to expand portable applications and develop panels for use in the housing and construction industries.

What Are Future Needs?

A growing population will place greater demand on energy resources, increasing the demand for energy efficiency. Greater demands on energy resources will require building designs that reduce heat loss in cold regions and minimize solar gain in hot regions. Population growth along coastal areas will increase chances of large population centers being hit by the heavy winds associated with these areas. The same is true for areas threatened by seismic activity.

Construction materials that contain recycled components that exhibit ductile/energy-dissipating characteristics would have special applications in seismic areas. Rigid materials and connections that resist high loads and then fail abruptly are more likely to result in extensive damage than those that exhibit plastic behavior and ductile failure. For example, cement-bonded-fiber composites exhibit a characteristic elasto-plastic load displacement. Research to improve their durability, connections, and panel configuration could result in a low-cost structural material that has good fire, insect, and decay resistance in addition to its seismic load advantage. Low-density, shear-resistant composites may have dual applications as shear walls and sound barriers for multi-family buildings.

Acceptance for any new product depends partly on its ability to show a definite economic advantage. Plywood, for example, was more than a one-to-one substitute for board sheathing: it offered reduced labor costs and application time, less waste on the job site, and improved lateral-load (earthquake, wind) performance. Once accepted, plywood completely replaced board sheathing. OSB, however, has offered no advantage other than price and there are still contractors who refuse to use it.

Molded products for housing construction open the market to innovative, energy-efficient, and wind-resistant structures. For example, moldable structural composites from recycled waste might be used to fabricate stress-skin-panel corners to replace the conventional three-stud corner. This would reduce heat loss, improve shear performance, and reduce wind pressures due to turbulence around building corners in heavy winds. These products also could provide more architectural possibilities than existing rectangular wood products. Shapes can be mass produced to form curved surfaces with little or no framing members, thus reducing labor and material costs.

High-density fiber composites from recycled waste could also be used as substitutes for wood flooring and could provide a good wear surface while being more dimensionally stable than solid hardwood flooring. Maintenance could be reduced compared to an open-celled wood such as oak. Possible applications could include bowling alleys, gym floors, and decorative office flooring. [Tom Marcin, (608) 231-9366]

Interest Increases in Plants as Medicine

Relatively recent technological developments have allowed improved screening of plants for potentially beneficial chemical compounds. Both public and private sectors have responded by beginning natural-products drug research. Markets for herbal remedies have also expanded, driven by increasing interest in health and alternative medicines.

The natural-plant-products industries are very diverse. It is estimated that about 50 percent of natural plant products are used in food-related industries, including medicinal infusions and unlicensed herbal remedies (dietary supplements). Another 25 percent are used in cosmetics, 20 percent in medicinal applications (ointments, creams, oils, etc.), and 5 percent for miscellaneous uses, such as insecticides and fungicides (1). Such diversity often results in various plants being used by multiple, and often unrelated, industries--for example, dietary supplements and cosmetics.

Medical Treatment Uses Plant Products

Plants are an important part of human medical treatment and health care. The World Health Organization estimates that 70 to 80 percent of the world's population relies mainly on traditional forms of medicine, of which plants are a major part. Plants also play a significant role in modern medicine. Approximately 25 percent of all prescriptions dispensed in the United States contain plant extracts or active ingredients obtained from, or patterned after, plant materials. With the worldwide prescription pharmaceutical industry assessed at roughly $150 billion, James Duke, an economic botanist with USDA, has estimated the current world market for plant-containing pharmaceuticals to be about $30 billion. Other estimates have suggested that U.S. medicinal plant imports alone could be worth over $1 billion annually.

In recent decades, there has been limited interest in research on plants for potential pharmaceutical uses. Prior to the mid-1980's, methods for screening plants were relatively slow, and only a handful of drugs made it to market from several decades of research. However, recent bioassay screening technology is faster, more thorough, and more economical than before. This helped lead to a new 5-year research program at the National Cancer Institute (NCI) in 1987, which was renewed in 1991 for another 5 years at an estimated cost of $3.8 million. In addition, several major pharmaceutical companies, specialized plant-research companies, universities, and botanical gardens have begun extensive natural-products research.

It may be years before the full economic impact of these programs is known. Discovery of useful natural compounds is only the first step. After finding a useful compound, organizations must find sources of raw materials (or alternatives such as semisynthesis or synthesis) to create large quantities of the product for extensive testing. NCI's Gordon Cragg estimates that preclinical tests, followed by clinical trials and approval by the U.S. Food and Drug Administration (FDA) may take as many as 15 years before a drug is ready for market. The cost incurred by the researching companies is tremendous, perhaps as much as $230 to $500 million in just proving a drug safe and effective to meet FDA standards. In addition, the companies generally seek patent protection, which can be a difficult task in itself, to ensure a return on investment.

Alternative Markets for Medicinal Plant Materials Expand

The costs of prescription pharmaceutical research make it difficult, if not impossible, for smaller organizations to undertake. However, the recent growth in natural food products and herbs as medicinal plants (marketed as dietary supplements) has created economic opportunities for individuals and organizations of all sizes. Steven Foster, an herb industry expert, has identified three primary markets for medicinal plants in the United States: pharmaceuticals, health and natural foods, and exports. European markets have potential, particularly Germany. In that country, herb products are manufactured according to recognized standards and allowed as treatments so long as they have no proven detrimental side effects. European phytomedicinal sales reached $2.2 billion in 1990, and have a projected annual growth of 10 percent (2).

Use statistics on natural plant products, other than for food or flavoring, are unavailable. For example, USDA Agricultural Marketing Service data on herbs are limited, and reflect only herbs used for food or flavoring. USDA Foreign Agricultural Service data on bulk dried herbs, spices, and essential oils cover only import trade at point of origin. These figures do not give any indication as to what products the herbs, spices, and oils will be used to create. They may end up in spice racks, dietary supplements, cosmetics, or personal-care items.

Because of the lack of statistics, estimating the size and growth rate of the alternative markets for medicinal plants is a difficult task. However, the recent growth in the health food industry is probably a good indicator of overall expansion. As reported in the June 1994 *Natural Foods Merchandiser*, the volume of sales in health-food chains reached $822 million in 1993, up 23 percent from 1992. Health-food chains are defined as chains with at least 150 stores that focus mostly on vitamins, supplements, and herbs. Much of this increase can be attributed to surging sales of herbs and dietary supplements, which often include herbs, essential oils, and other plant materials. One industry expert has placed the retail value of herb products and homeopathic remedies at over $1 billion.

One of the most popular and high-valued herbs in both domestic and international markets is ginseng, a medicinal herb for which some statistics do exist. According to U.S. Fish and Wildlife Service data, nearly 1.4 million pounds of certified, cultivated ginseng were produced in the United States in 1993, mostly in Wisconsin. That same year, approximately 110,000 pounds of certified wild ginseng were collected in the United States, with large amounts coming from the Appalachian Mountain region. Ginseng prices vary greatly, depending on quality and type. American Ginseng generally sells for more than Asian Ginseng, and wild ginseng more than cultivated. U.S. Department of Commerce trade data show that nearly $80 million worth of ginseng was exported in 1993.

Growing retail sales of herbal products is evidence that many Americans are beginning to use herbal remedies as alternatives to common over-the-counter drugs. The most common uses for herbal remedies are as cold/flu medicines, laxatives, diuretics, antacids, stress reducers, and sleep aids. Interest in Chinese herbs is growing as Americans and Europeans learn about traditional Chinese medicine. One California herb-and-spice company has noticed dramatic increases in sales of ginkgo leaf and dong quai root, while maintaining solid sales of domestically grown herbs, such as echinacea and goldenseal. Other top selling herbs for various companies include chamomile flower, psyllium seed husk and powder, peppermint, licorice, and ginger (4).

Industry experts note the increasing importance of quality products, particularly organically grown herbs. Many supplement producers are looking for quality herbs to produce their formulas, which may boost domestic growers' chances to compete with imports. Many herbs are currently imported due to lower labor costs in producing countries, but as the demand for high quality and organic products grows, so to do the chances for domestic producers with highly skilled labor and ideal growing conditions, such as greenhouses. Foster suggests that farmers interested in growing medicinal plants must first do extensive research on particular commodity markets and production practices.

The Supplements Industry Now Subject to Regulation

In October, Congress passed and the President signed the Dietary Supplement Health Education Act of 1994. For the first time, dietary supplements are legally defined as vitamins, minerals, herbs, etc., intended to supplement the diet by increasing dietary intake, but not intended or represented as a conventional food or sole item of a meal or diet. This definition excludes ingredients that fit the definition of a food additive (flavoring, seasoning, etc.) or a drug.

Other major aspects of the act:

- Authorize FDA to remove a supplement from the market if it is found unsafe. The burden of proof rests with FDA.

- Authorize FDA to promulgate new good-manufacturing-practice regulations, which will be used to ensure quality products.

- Disallow direct health claims on product labels without FDA approval, but permit truthful and nonmisleading claims on how ingredients affect the body's structure or function so long as the statement is registered with the Secretary of Health and Human Services, and the following disclaimer is on the label: "This statement has not been evaluated by the Food and Drug Administration. This product is not intended to diagnose, treat, cure, or prevent any disease." If this provision is not followed, FDA can remove the product from the market.

- Allow third party information to be made available in the store where a product is sold so long as it is truthful and nonmisleading, independent of a specific manufacturer or product, and displayed separately.

- Create a 2-year commission to evaluate a more effective health-claims approval process.

- Create a new Office of Dietary Supplements within the National Institutes of Health (NIH) for the purpose of further exploring the potential role of dietary supplements in improving health care.

Alternative Medicines and Phytochemicals Are Hot Research Topics

The Federal government is interested in alternative medicines as well. NIH now has an Office of Alternative Medicine (OAM), which conducts and sponsors research on medical practices and interventions that do not have significant documentation of safety and effectiveness in the United States, are not generally taught in medical schools, or are generally not reimbursable by insurance companies. OAM will hold regular meetings with FDA in order to "enroll its cooperation in reevaluating the interpretation of current rules and regulations governing device, herb, and homeopathic-drug research and use" (3). Currently, OAM has issued two grants of about $30,000 each for research on Chinese herbs and their effectiveness in treating common warts and hot flashes.

OAM believes that pharmaceutical companies also may be interested in studying traditional herbal formulas, even though they may not be proprietary. If a formula was proven safe and effective and approved by FDA, the company submitting the research could possibly receive a new-drug exclusivity award that could last 3 to 5 years. During this time the company would have exclusive rights to market the formula as a drug, giving it an opportunity to receive a return on its research investment. As stated earlier, many pharmaceutical companies are indeed screening natural plant products for new drugs, but much of this research is focused on tropical plants and not necessarily on herbal remedies.

Many phytochemicals (compounds that exist in plants) have been shown to have various effects on human health, ranging from toxic to nutritionally beneficial. Scientists have begun isolating these chemicals and studying their properties. NCI's Designer Foods Program is currently working on identifying, isolating, and quantifying beneficial chemicals in foods. [Charles Plummer, (202) 219-0009]

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Guayule Research Continues

Current research and recent studies on the hypoallergenic nature of guayule latex show promising results for the future demand of guayule latex products. Prior clinical tests have shown that patients who have severe reactions to Hevea latex did not react to latex derived from guayule. The results of these studies have been verified in the laboratory by Katrina Cornish and Deborah Siler, researchers with USDA's Agricultural Research Service (ARS). Their research concludes that even highly purified Hevea rubber still reacts strongly with certain antibodies, indicating that highly purified Hevea latex would not necessarily prevent allergic reactions in individuals who have already developed an allergy to Hevea.

Recent estimates indicate that as many as 17 million Americans may be affected by Hevea allergy, and this number is likely to climb as more people come in contact with latex products. Reactions can range from mild irritation to life-threatening. People with type-1 allergies to Hevea can still be affected by highly purified Hevea products, which opens the market to products such as guayule latex.

ARS is investigating commercialization opportunities for guayule latex. Small-scale processing trials of guayule latex have been successful, and guayule test plots have been grown in Arizona, Texas, and California. It is believed that even a small share of the U.S. latex glove market would be enough to make it economically feasible to produce guayule for its hypoallergenic latex, even at current yields. ARS has applied for a patent on latex rubber from guayule.

Biogas Production from Animal Manures: What Is the Potential?

by

Donald L. Van Dyne and J. Alan Weber[1]

Abstract: Livestock producers who operate large-scale confinement operations, such as dairies and hog farms, are looking for ways to handle and dispose of animal wastes that are cost effective and meet odor and pollution regulations. Farm-level production of biogas (using anaerobic digesters) is one solution for livestock producers that also will help control methane emissions into the atmosphere. Methane is a greenhouse gas that contributes to potential global warming. Biogas is 60- to 65-percent methane; carbon dioxide and trace amounts of water and other gases, such as hydrogen sulfide, account for the remaining 35 to 40 percent. It is a medium-Btu fuel that can be used to generate electricity or burned in natural-gas or propane boilers and space heaters. Heat, fertilizer, and soil amendments are coproducts of the digestion process that contribute to its economic viability.

In general, with current technologies, anaerobic digesters require warm climates, large volumes of manure, high local electricity rates, and daily maintenance and management to be profitable. The Federal government, through the AgSTAR Program, is promoting biogas production as a way of generating extra income for farmers, reducing greenhouse gasses, and improving water quality. Four case studies demonstrate that farm-level production of biogas is feasible under local conditions.

Keywords: livestock manure, methane, anaerobic digesters, biogas.

Methane-recovery systems and anaerobic digesters first gained popularity in the United States during the 1970's. At the time, alternative energy sources were promoted due to the rising costs of petroleum-based energy. Both state and Federal agencies provided financial assistance to help construct farm-level, methane-recovery systems. However, many systems were overdesigned and difficult to maintain. Subsequent failure and/or poor performance of a number of anaerobic digesters reduced confidence in these systems. Since then, improved technology and increased concern for the environment have renewed interest in the feasibility and use of methane-recovery systems.

Managing Animal Wastes To Minimize Pollution

The major problems associated with livestock and poultry manure include: surface water and groundwater contamination from nitrogen and fecal bacteria; methane emissions from anaerobic digestion of manure; and air pollution resulting from the formation of odor, dust, volatile organic acids, and ammonia.

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The first comprehensive Federal efforts to improve water quality were implemented in the early 1970's with the passage of the Clean Water Act (CWA). The initial focus of the CWA was on regulating point sources of pollution, primarily municipal sewers and industrial plants. Subsequently, agricultural point sources were targeted, including livestock production systems that use manmade structures, such as feed pens, confinement buildings, slurry tanks, pipes or culverts, holding ponds, lagoons, irrigation systems, and dead-animal disposal facilities.

Concentrated animal feeding operations (CAFO's) are considered point-source polluters. Livestock production is included under the CAFO definition if:

- Animals are stabled or confined and fed for 45 days or more in a 12-month period;
- Vegetation is not sustained during the normal growing season in any portion of the lot or facility;
- The feedlot must have either 1,000 animal units and discharge pollutants, or between 301 and 1,000 animal units if pollutants are discharged into navigable waters through a manmade conveyance or into navigable waters that originate outside of, but come into contact with, the area used by the operation;

- Pollutants are discharged in absence of a 25-year-frequency, 24-hour-duration rain storm (a theoretical "super storm" as defined for each specific state and region).

Smaller facilities with less than 300 animal units may be designated as point-source polluters if they present a significant risk to water quality by discharging directly into navigable waters through the facility or through a manmade conveyance. These facilities are evaluated on a case-by-case basis, but most are classified as nonpoint sources of pollution and face a different set of regulations.

Livestock production facilities that are considered point-source polluters must obtain a National Pollutant Discharge Elimination System permit as mandated by Section 402 of the CWA. Livestock point sources are regulated by the U.S. Environmental Protection Agency (EPA) or state environmental agencies acting on its behalf.

The CWA also created a program to control nonpoint sources (NPS) of pollution and to protect groundwater. Section 319 of the act requires each state to submit an assessment of state waters not expected to meet water quality standards because of nonpoint-source pollution and submit a management program for controlling such pollution. The NPS program has evolved more slowly than efforts to control point-source pollution because the latter was easier to regulate and more cost-effective to implement. More recently, NPS pollution has received additional attention, and controlling it has typically involved implementing best management practices (BMP) rather than enforcing specific regulations. Most BMP's include educational, technical, and financial incentives designed to encourage better land- and resource-management practices, plus more prudent use of pesticides and fertilizers.

In response to these water-pollution regulations, livestock producers have built containment facilities--such as lagoons, ponds, and other types of storage devices--to prevent runoff and leaching of nutrients from animal manure. While the actions have helped to reduce water pollution, they have actually increased methane emissions. Under the anaerobic (oxygen-free) conditions that exist in the containment facilities, bacteria convert the organic matter in manure to methane.

Methane released into the atmosphere is a large contributor to potential global warming, second only to carbon dioxide. Methane is 60 times more effective at trapping heat in the atmosphere than carbon dioxide over a 20 year period. Methane concentrations in the atmosphere have more than doubled over the last two centuries and continue to rise annually. Because methane has a short lifespan in the atmosphere (11 years compared with 120 years for carbon dioxide), controlling emissions will have a rapid impact on mitigating potential climate change (1).

The Federal government does not have formal rules or regulations regarding methane emissions from agriculture. However, the AgSTAR program, initiated by EPA's Global Change Division, is currently assessing the technical and economic feasibility of capturing methane for conversion into energy sources for farm use.

Several states account for most of the methane emissions from animals. An EPA study estimated that in 1990 methane emissions from dairy and hog production in the United States were 734,000 metric tons and 1.1 million metric tons, respectively (table A-1). Emissions from dairy farms were highest in California, while hog farm emissions were high in Missouri, Iowa, Illinois, North Carolina, and Indiana.

Converting Manure into Biogas?

Anaerobic digesters use bacteria to convert manure into biogas, which is a combination of 60- to 65-percent methane (CH_4), carbon dioxide that accounts for most of the remaining 35 to 40 percent, and trace amounts of other gases, such as hydrogen sulfide and ammonia. These digesters operate under anaerobic conditions and within certain temperature ranges. The methane in biogas can serve as a replacement for natural gas to produce heat or electricity. In addition, anaerobic digesters stabilize the remaining manure solids into a nearly odorless product that can be used as a soil amendment and fertilizer.

The potential for anaerobic digestion of animal manure in the United States depends on the manure handling practices used by producers and the size of their operation. Methods of manure disposal vary widely depending on the type of animal (table A-2). Some practices are more amenable to biogas production than others. For instance, manure left by beef cattle on range or pasture is not economically collectable for anaerobic digestion or other

Table A-1--Methane emissions from dairy and hog facilities in selected states, 1990

State	Emissions
	Metric tons/year
Dairy	
California	174,978
Texas	63,708
Missouri	54,522
Washington	44,031
Wisconsin	22,335
Other states	374,062
Total	733,636
Hog	
Missouri	127,050
Iowa	117,518
Illinois	113,213
North Carolina	103,261
Indiana	90,224
Other states	572,011
Total	1,123,277

Source: (6).

uses. An estimated 90 percent of poultry manure is collected using solid disposal systems. While most of this manure is economically collectable, feathers and certain types of poultry litter can clog anaerobic digesters.

Manure production from a 1,250-pound Holstein milk cow is estimated at 1.75 cubic feet per day (table A-3). Also, a sow unit (sow and pigs) is expected to produce a similar volume of manure on a daily basis. Biogas production from a properly functioning anaerobic digester using these sources is estimated to range from 54 to 56 cubic feet per animal per day. The actual volume of biogas will vary depending on the type of manure-collection system. For instance, one farmer estimated that, using a flush manure-handling system on his farm, manure from one dairy cow will produce 60 cubic feet of biogas per day, while a scrape system will yield up to 85 cubic feet per day.

Over 20 private methane-recovery systems are in operation across the United States. An additional six experimental systems are housed at various universities (6). Although there are many different types of digesters that could be used by livestock producers, only covered lagoons, plug-flow digesters, and complete-mix digesters are used on livestock farms due to capital investment and management requirements.

The simplest anaerobic digester is the lagoon. Manure progresses naturally through all three chemical stages of methane formation. Significant quantities of biogas can be produced from a covered lagoon system that is properly designed and in which the manure is held over 60 days (6). A floating cover is placed over the lagoon and biogas is collected underneath the cover. Maximum biogas generation occurs in the summer, while the rate of gas production decreases with colder temperatures. Some gas can be stored under the cover and used later; however, long-term storage is not economical.

Plug-flow digesters are designed to accept a daily plug of new manure. As a new plug is added, an equal amount of effluent is discharged from the opposite end of the digester. The retention time for most plug-flow digesters is between 20 and 30 days. Most plug-flow systems are designed to move manure and effluent by gravity, thus eliminating the need for pumps. In addition, plug-flow digesters must be designed to prevent the passage of air into the digester when manure is added, as well as when effluent is discharged.

Complete-mix digesters are usually constructed for livestock operations that generate large amounts of low-solids manure (6). The basic concept is similar to the

Table A-2--How manure is handled in the United States 1/

Livestock and poultry type	Liquid disposal			Solid disposal		
	Anaerobic lagoons	Liquid slurry and pit storage	Daily spread	Solid storage and drylot	Pasture, range, and paddock	Litter, deep pit, and others
	Percent					
Dairy cattle	10	23	37	23	0	7
Nondairy cattle	0	1	0	14	84	1
Poultry 2/	5	4	0	0	1	90
Sheep	0	0	0	2	88	10
Swine	25	50	0	18	0	6
Other 3/	0	0	0	0	92	8

1/ Totals may not add due to rounding. 2/ Includes chickens, turkeys, and ducks. 3/ Includes goats, horses, mules, and donkeys.
Source: (5, 6).

Table A-3--Manure production from various livestock, and biogas yield from a properly functioning anaerobic digester

Animal	Average animal weight	Manure production 1/	Expected biogas yield	Recommended retention time	Electricity production 2/
	Pounds	Cubic feet/day	Cubic feet/animal/day	Days	kW hours/day/animal
Holstein milking cow 3/	1,250	1.75	54.00	20	2.00
Beef feeder steer	800	1.00	25.00	15	1.00
Feeder pig	130	0.16	5.60	15	0.20
Sow and litter 4/	1,300	1.75	56.00	15	2.00

1/ Solids, liquids, and 15 percent extra volume from waterers and wash water. 2/ Assumes biogas has an energy value of 600 Btu per cubic foot and the generator operates at 21 percent overall efficiency. 3/ Increase digester volume by 50 percent if manure from dry cows and replacement stock is added. 4/ The average weight of a productive sow and pigs at any time from farrow to finish. A sow produces an average of 16 pigs annually.
Source: (3).

plug-flow digester. Animal manure is collected in a mixing tank and then transferred to the digester. Because the manure is mixed, it creates a good environment for biogas production. The system does not have a fixed retention time due to the way the manure is added and mixed.

In order to protect the digester and to maintain the necessary temperatures for biogas production, some producers enclose their systems in greenhouses or build wind fences around them, while others recycle generator heat back to the digester. Greenhouses also can be built near digesters to use excess heat when needed and carbon dioxide to stimulate plant growth.

Actual purchase and installation costs for anaerobic digesters vary widely. However, costs developed for a 1,000-cow dairy operation in a warm climate give an indication of investment required. The estimates--$145,000 for a covered lagoon, $154,000 for a plug-flow digester, and $213,000 for a complete-mix system--include the purchase of an engine generator to use the biogas and the assumption that 55 percent of the dairy manure will be collected and processed. The life expectancy of the complete-mix digester is estimated to be 20 years, while the others are 15 (2).

Of the three types of systems, covered lagoons appear to be an economical choice for swine and dairy farms in the Southeast and West that use hydraulic flushing for manure collection and a lagoon system for their waste handling system (2). Lagoon systems as far north as North Carolina have proven successful in economically producing biogas for most of the year. A plug-flow-digester system is more expensive than a covered lagoon, but it still can be economically viable option under certain climatic conditions, depending on the value received for the coproducts of the process (heat, carbon dioxide, and fertilizer/soil amendments).

Complete-mix systems have higher capital, operating, and maintenance costs than lagoon or plug-flow digesters (table A-4). Therefore, the complete-mix system is probably best suited for large livestock operations that are in climates too cold for covered lagoons or those that handle manures with low solids content (2).

Table A-4--Characteristics of selected types of anaerobic digesters

Digester process	Process complexity	Operational complexity	Capital costs	Operating costs
Covered lagoon	low	low	low	low
Plug flow	low	low	low	low
Complete mix	medium	medium	medium	medium

Source: (7).

Using Biogas on the Farm

Biogas produced from farm-level, methane-recovery systems is a medium-Btu-content fuel. Technologies exist to remove impurities to produce a higher quality fuel. The amount of clean-up that is necessary depends on the composition of the biogas and its intended use. Primary objectives of clean-up processes are usually either to remove the corrosive elements (hydrogen sulfide and water vapor) or to remove both the corrosive elements and those elements that dilute the methane level in the biogas and its heating value (carbon dioxide and nitrogen). Although the removal of sulfur is sometimes recommended to avoid excessive engine wear, some methane-recovery systems have been very successful without cleaning the biogas before is it used to fuel an engine generator. High-quality oil changed at regular intervals is cheaper and as effective as sulfur-removing mechanisms.

Fueling engine generators, boilers, and space heaters are the most common farm uses of biogas. Most livestock producers that install an anaerobic-digestion system to dispose of animal waste will burn the biogas in an engine generator to meet the farm's electrical demands, produce heat and fertilizer, and sell any excess electricity to a local utility company.

Small engine generators usually convert only 20 to 25 percent of their fuel, such as biogas, into electricity (3). A majority of biogas energy is actually converted into heat. In order to utilize this energy, heat exchangers for the exhaust system and engine coolant are used to recover 40 to 50 percent of the energy. This heat can be used to maintain the correct temperatures for anaerobic digestion and other purposes, such as heating water for cleaning equipment and facilities.

Selling the excess electricity to the local utility company may involve installing an automatic interrupting device, which can isolate the farm generator from the utility lines when there is a loss of power by the utility or a fault in the generator's circuitry.

Natural-gas and liquid-propane-gas appliances (boilers and space heaters) will operate on biogas. However, the lower energy density of the biogas results in reduced heat output (3). In order to maintain necessary levels of heat generation, relatively inexpensive modifications are sometimes necessary. This is usually done by enlarging the size of the orifice to allow more gas to pass through to the appliance. Assuming a 65-percent methane content, biogas would require an orifice 1.39 times larger than the one for natural gas or 1.72 times larger than the one for propane to maintain a constant temperature.

Barriers to Using Methane-Recovery Systems

There are informational, managerial, and financial barriers to widespread use of methane-recovery systems. Many digesters built during the 1970's failed because of poor design, improper maintenance, or low local electricity prices (6). While the technical problems have been mostly resolved for commercial-sized livestock operations, more demonstrations of successful systems are necessary to verify operation on a continuing, dependable, and economical basis.

Careful management is essential to maintaining optimum digester conditions and output. Although most managers of large livestock operations have little time to devote to other activities, anaerobic digestion and electricity generation is an additional enterprise that must be looked after on a regular basis. Unlike the 1970's, however, today's technologies require less management. The problems that must be dealt with include variable quantities and qualities of manure, inadequate heat maintenance, and buildup of nondegradable materials in digesters.

The main financial barriers that exist for livestock producers interested in methane-recovery systems are initial design and installation costs, limited access to capital, and low buy-back rates for the electricity from local utilities.

AgSTAR Promotes Use of Digesters

The goal of the AgSTAR program is to help livestock and dairy producers lower capital, operational, and maintenance costs; control odor and methane emissions; maintain water quality; and utilize a renewable domestic energy source--by encouraging more widespread use of methane-recovery systems. In addition to EPA, USDA and the U.S. Department of Energy are also involved in the program. AgSTAR is considered a key component of President Clinton's Climate Change Action Plan, which promotes U.S. ingenuity and efficiency as solutions to global warming.

AgSTAR, a voluntary program, was designed to help producers overcome obstacles to adoption. Once fully operational, it will have three components: the Partner Program, the Ally Program, and the Utility Program (4). The Ally and Utility Programs are aimed at people who design, promote, build, sell, and install manure digesters. EPA will work with utilities, universities, private firms, and others to promote reliable methane-recovery systems, provide information, and develop financing mechanisms.

The Partner Program encourages livestock producers to investigate the viability of constructing and implementing a methane-recovery system. To become an AgSTAR partner, a producer signs a Memorandum of Understanding with EPA. The producer agrees to survey his/her facilities, install AgSTAR-selected technology where profitable, and appoint a manager to oversee participation in the program.

In return, EPA provides technical support. For example, producers receive a methane-recovery handbook and reference guide for specific livestock-rearing methods and manure-management strategies. Included in the manual are topics such as odor control, technical design, energy applications, economics, case studies, financing options, manure-management principles, and nutrient-management strategies. Producers who enroll also have access to a computer software package that enables them to survey their facilities, assess energy options and applications, and select the most profitable digester. The software will generate financial reports that allow managers to compare the economics of a present waste-management system with a methane-recovery system. AgSTAR will also manage high-visibility demonstration projects and provide a directory of participants.

What Are the Economics?

Livestock producers and dairy farmers must deal with disposing of animal waste products, including manure. Anaerobic digestion of animal manures can make economic sense for farmers in some cases when they are used to generate electricity, heat, fertilizers, and soil amendments for farm use. Using digesters to produce methane to sell off-farm does not make sense because the gas is not pure enough for natural gas companies and there is no pipeline collection system in place. Electricity generated in excess of a farm's needs often can be sold into the local electric power grid. Prices received vary from a low of 3 cents per kilowatt hour to a high of 15 cents. The variation is due to different local rates, the need for additional electricity in the region, the need for enhanced environmental quality, and other factors.

Producing biogas solely for electricity generation requires rates greater than 6.5 cents per kilowatt hour. Values associated with coproducts enhance the economic feasibility of any system, especially when rates are below 6.5 cents. Society must also recognize the importance of reducing methane emissions, controlling odor, improving water quality, and generating rural economic activity.

A recent study evaluated covered lagoons, plug-flow digesters, and complete-mix systems using three investment strategies: net present value, internal rate of return, and simple payback period (2). In many cases, covered lagoons were found to have an economic advantage due to lower capital, operating, and maintenance costs. However, lagoons are usually limited to relatively warm regions. Moreover, the results are sensitive to local electricity prices and coproduct values.

Most analyses suggest that only larger livestock operations would be able to economically justify a methane-recovery system. Most dairies require at least 500 head of milking cows and most swine operations require at least 2,000 to

3,000 head for a methane-recovery system to be economically viable (based on 1993 electricity prices, an average milking cow weight of 1,400 pounds, and an average hog weight of 138 pounds) (6).

Although a major portion of U.S. milk production originates in the northern Midwest, the dairies there have relatively small herds. Combined with the cold climate, these operations are generally not the best candidates for manure digesters. Opportunities exist, however, for large dairies in California, Arizona, Texas, and Florida and emerging large-scale operations in New Mexico and Kansas.

Similar circumstances exist for swine herds. A majority of hogs in the United States are raised in Iowa, Illinois, Indiana, Missouri, and North Carolina. Most of the hogs raised in Iowa, Missouri, and Indiana come from small herds. However, large increases in hog numbers by a few vertically integrated hog producers in North Carolina, Arkansas, and Missouri are rapidly changing the structure of the hog industry, which could make anaerobic digestion more feasible.

Case Studies Show Methane-Recovery Systems Can Be Profitable

While the technical and economic feasibility of biogas production is site specific and highly dependent on system management, the following case studies provide information on several livestock operations that have been successfully producing biogas.

Mason Dixon Farms, Gettysburg, PA, is a 2,700-head dairy cow operation. The owner built his first anaerobic digester in 1979 when the operation had 600 cows. As the herd expanded, a second and third digester were added to the biogas system. All three digesters are located underground, which allows for a relative constant digester temperature through the year, thus minimizing weather-related problems. The owner expanded the digestion system because he found that anaerobic digestion was a profitable way to handle animal waste.

In addition to generating electricity, odor reduction is a very important characteristic of the digesters because the farm is located near populated areas. The nitrogen in manure is in the form of ammonia, which is very volatile. During the digestion process, the ammonia changes to ammonium nitrate, which is more stable. The owner also uses the system's liquid effluent as a fertilizer for cropland and sells the remaining solids to area nurseries as a soil amendment. The pH level of this farm's manure is around 4.5, but the digested effluent has a pH level of 7.3 to 7.5. Therefore, liming the cropland is no longer necessary.

The owner has invested $250,000 (1991 dollars) in the system. After considering maintenance costs, the value of generated electricity, and the effluent, the net annual income from the system is around $90,000 per year. He emphasized the importance of maintaining the specific herd population for which the digesters were designed. He does not clean his biogas prior to use, and the three engine generators have operated for several years with normal wear and no unexpected operational problems.

Langerwerf Dairy, Durham, CA, is a family-owned operation with a 500-head dairy cow herd and 300 acres of cropland. In 1982, they installed a plug-flow digester to produce electricity, hot water, composted solids, and liquid fertilizer. The decision was based on the rising costs of energy and the problems and costs associated with manure disposal. The annual cleanout of the existing manure lagoon was costing from $10,000 to $15,000.

Manure is scraped from the dairy barns daily and deposited into a 20,000-gallon mix/holding tank. The mixed manure is pumped from the tank to the anaerobic digester, which holds 225,000 gallons. The collection bag can store about one-third of a day's biogas production. They now have a greenhouse over the digester to protect the top from weather and wind damage.

The biogas is piped through a filter before reaching the engine generator set. The filter removes most of the water and hydrogen sulfide. The engine/generator set is a 85-kilowatt (kW), induction-type generator powered by a six-cylinder Caterpillar 3306 natural-gas engine. The engine was modified to run on lower Btu biogas. The generator produces, on average, 40 kW of electricity per day. The dairy uses about 35 kW and the excess is sold to the local utility. Waste heat from the engine's cooling system and exhaust are used to provide hot water for the dairy and help maintain the temperature of the digester.

The effluent is pumped to a vibrating screen that separates the solids and liquids. The solids are sold to landscaping businesses, used as a soil amendment, or spread as a bedding material for dairy cows in the freestall barn. Liquids are applied to cropland as a source of fertilizer. The liquid effluent remaining after the anaerobic process has very little smell, which reduces the potential for odor problems in a densely populated area.

The system requires about a half an hour of labor each day. The Langerwerfs experienced premature engine problems when they first started their system and had to rebuild the engine after 5,000 hours of operation, well short of the normal 24,000 hours. Since then, they have changed the type of engine lube oil. Testing after 6,000 hours showed engine wear to be within normal limits.

The total installed cost, including site improvements and repair costs in the first couple of years, was $203,800. An 8-year economic analysis of this system shows a total cost for capital, interest, labor, and maintenance to be $324,968. Some of the credit was obtained on preferential terms. Total income for those 8 years was estimated to be $692,900. The annual return on investment without considering tax credits is almost 30 percent and over 50 percent when tax credits are included.

Royal Farms, Tulare, CA, is an 8,000-head, farrow-to-finish hog farm. About 2.5 tons of manure solids are removed from the barns each day by flushing the confinement houses with water. The water-flush system uses 50-percent new water and 50-percent recycled water. The manure slurry is pumped into an anaerobic lagoon system. The biogas that is produced fuels a 75-kW engine generator. The electricity produced is used on the farm, with the excess sold to the Southern California Edison Company.

The initial capital investment was $89,000. First-year revenue from the electricity was about $36,000. The payback period for the system was about 3 years.

Harlan Keener, Lancaster, PA, owns a sow farrow-to-finish operation. He added a manure digester in 1984 when he expanded from 600 sows to the current 990. Potential problems with the laws regulating odor emitted from his confinement system prompted Mr. Keener to construct an anaerobic digester for his operation.

Manure is moved by a sump pump from the confinement houses to two mixing pits, each of which can hold up to 25,000 gallons of animal waste. Twice a day, the manure slurry is pumped into the digester. The digestion process takes 18 to 23 days, depending on conditions. A heavy rubberized tarp that covers the 350,000-gallon digester collects the biogas, which is then piped into the generator. Keener's system produces an average of 125 kW on a continuous basis and can be used to supply the farm's electrical needs or sold to the local utility company. The effluent contains 1-percent solids and is stored in a concrete holding tank or two holding ponds until it is used by area farmers as fertilizer for their cropland.

Conclusions

The production of biogas by anaerobic digestion of manure will reduce methane emissions into the atmosphere if the gas is collected and used for heating or to generate electricity. While technical barriers that occurred during the 1970's have largely been overcome, economic viability of farm-level methane-recovery systems depends on the size of livestock operation, management capabilities, and the value of the biogas products. Livestock producers across the United States have profitably used all three types of digestion systems--covered lagoon, plug flow, and complete mix. While the case studies have been successful and generated high rates of return, other systems have failed because of poor design and inadequate management.

Much of the current interest in anaerobic digesters is from large operations in milder climates. However, as the Mason-Dixon-Farms case study proves, cold-weather operations are both possible and profitable. In the case studies, producers were able to recoup their initial investment in equipment and facilities in about 3 years. While this is an excellent return on investment for agricultural enterprises, such a rate should not be expected for all installations.

After a system has been properly designed and installed, management of the enterprise is the key to success. Producers must be willing to devote to the system the time and effort required to assure continued profitable operation.

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Pulping Catalysts from Lignin

by

Joseph J. Bozell, Donald R. Dimmel, and Arthur J. Power[1]

Abstract: Lignin, a common material in trees and woody plants, is currently a byproduct of pulp and paper production. However, joint research at the National Renewable Energy Laboratory and the Institute of Paper Science and Technology is aimed at broadening commercial uses of lignin. One project is assessing the potential of converting lignin into anthraquinone-like pulping catalysts. Anthraquinone (AQ) improves kraft pulping, but its cost, which ranges from $4.00 to $4.50 per pound, hinders widespread use.

Three processes for converting lignin into pulping catalysts were evaluated for their technical and economic feasibility. Preliminary results indicate that two of the processes appear viable. Amortized production costs for using lignin from kraft pulping, without intermediate conversion to vanillin and syringaldehyde, and lignin from organosolv pulping were estimated to be $1.24 and 79 cents per pound, respectively. Comparing these two processes to competing petrochemical-based, AQ-producing methods, showed that the lignin-based routes were potentially the most cost effective.

Keywords: Lignin, pulping catalysts, anthraquinone, kraft pulping, organosolv pulping.

Lignin, the material in trees and woody plants that differentiates them from herbaceous plants, is one of the most underused renewable sources of carbon. In nature, lignin makes up as much as 30 percent of the carbon in organic matter (1). Lignin, cellulose, and hemicellulose are the three major components found in wood.

However, lignin, a byproduct of pulp and paper production, is now used primarily as in-plant fuel. Commercial operations for isolating and converting the lignin from pulp mills to other materials are limited. Joint research at the National Renewable Energy Laboratory (NREL) and the Institute of Paper Science and Technology (IPST) is aimed at broadening the commercial uses of lignin as a chemical feedstock and converting it into useful, higher value compounds such as pulping catalysts.

Anthraquinone Can Improve Kraft Pulping

Roughly 80 percent of the paper made in the United States is produced using the kraft pulping process. Wood is heated with a base and sodium sulfide, which helps separate the wood components. The kraft process produces a cellulose fraction, which is made into paper, and a fraction containing the lignin, which is burned as fuel during recovery of the pulping chemicals. The kraft method is widely used because it rapidly separates the wood components, can utilize different types of wood, produces a strong pulp for paper manufacture, and has low chemical costs.

However, the kraft process also has a number of shortcomings. The pulp yield is relatively low and the pulp is highly colored, requiring extensive bleaching. The sodium sulfide contributes to the odor given off from kraft pulp mills. Plus, mandatory environmental safeguards and recovery of the pulping chemicals requires high capital investment.

A possible solution to several of these disadvantages was discovered in 1977 with the report that adding small amounts of anthraquinone (AQ) significantly improves the efficiency of the pulping process (2). This discovery has since become one of the most widely studied effects in paper chemistry (3). Many advantages of adding AQ to pulping processes have been reported:

- The rate of separation increases. This can result in either a faster rate of pulp production with the same amount of pulping chemicals used or lower chemical use at the same rate of production.

- The effects of AQ are seen with very low amounts. A significant increase in component separation occurs with as little as 0.01 percent by weight (based on the starting weight of the wood) of added AQ (4).

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An effect has even been observed when waste streams from AQ-catalyzed pulping reactions are recycled into subsequent pulping runs (5).

- Kraft pulp is bleached to remove residual lignin not separated during initial pulping. AQ has been suggested as a key component in the development of new processes that pulp wood for longer periods of time to remove greater amounts of lignin. In the past, such processes resulted in unacceptable decreases in the yield and strength of the pulp. In the presence of AQ, however, yield and strength are maintained even during long-term pulping runs. These new processes decrease the amount of residual lignin in the pulp and, thus, reduce the amount of bleaching needed to obtain a bright, white pulp (6).

- Kraft pulping currently uses relatively high levels of sodium sulfide. AQ can replace sodium sulfide and facilitate an evolution from high-sulfur (kraft) to low- or nonsulfur processes. Nonsulfur pulping does not have the bad odors associated with kraft pulping. The disadvantage of nonsulfur/AQ pulping is that pulp strength is reportedly lower than for simple kraft pulping. However, recent research aims to overcome this disadvantage (7).

All of these advantages may not occur simultaneously, but they can provide economic benefits to mill operators and lessen the potential for air and water pollution (3).

Making AQ From Lignin

Despite the reported advantages of AQ-catalyzed pulping, the current cost of AQ, which ranges from $4.00 to $4.50 per pound, hinders its general use, except under certain circumstances. For example, where wood costs are high, such as in Japan, pulping yields take on greater importance and AQ-type processes are common. As part of the NREL-IPST program, scientists have been investigating ways to prepare AQ or AQ-like pulping catalysts at a cost low enough to make it attractive for general industry use and have found lignin to be a suitable starting material (8-10).

Lignin has a number of attractive features as a raw material for AQ production. It is inexpensive (3 to 4 cents per pound when used for fuel) and is readily available as a byproduct from the paper industry. A variety of different lignin sources are available. The NREL-IPST effort is directed primarily at converting lignin from the kraft process to pulping catalysts because it is the dominant U.S. technology. The program also is investigating the use of organosolv lignin (lignin separated from wood using organic solvents) as a starting material, because it exhibits some chemical-property advantages over kraft lignin. However, its availability is much lower than kraft lignin.

The research, supported by the U.S. Department of Energy's Office of Industrial Technologies, focuses on both the scientific and economic aspects of commercializing a process that uses lignin as a feedstock. Since its inception, the program has been driven by three key factors: the process must be inexpensive, environmentally benign, and fit well with existing pulping technology. The NREL-IPST approach to the synthesis of pulping catalysts from lignin is divided into two stages: lignin processing and chemical processing.

The lignin processing stage involves selectively isolating a low-molecular-weight (LMW) fraction from lignin (11). In theory, whole lignin could be used directly in the subsequent chemical-processing stage. However, chemical reactions occur within the lignin component during and after pulping that result in a mixture of polymeric and oligomeric materials of widely differing molecular weights. From an economic perspective, using whole lignin is unattractive because it would increase chemical costs (12). It would also be difficult from an operational standpoint because of the heterogeneity of the mixture. Therefore, LMW lignins are isolated to serve as starting materials. Two methods for separating this LMW fraction have been evaluated: extraction using conventional solvents and extraction using supercritical carbon dioxide in the presence of small amounts of organic solvents (13).

The second stage of the process, chemical processing of the LMW fraction, involves two steps. First, the LMW lignin is oxidized to give a mixture of benzoquinones (intermediate chemicals whose structure makes up the core of AQ). Second, the benzoquinones are converted to pulping catalysts by adding chemicals with the appropriate number of carbons. AQ-like materials are formed during the second reaction, but the final product is a mixture of different compounds that show activity as pulping catalysts. For example, isoprene is used in the reaction because the AQ derivative obtained, dimethylanthraquinone, has been shown to be twice as active as AQ in pulping studies.

Three Base Cases Were Analyzed

A key aspect of the NREL-IPST program is an ongoing technoeconomic evaluation of the various stages of the process. Three base-case scenarios were prepared as a starting point for the analysis. Two were based on the use of kraft lignin as a starting material and one was based on organosolv lignin. Once the base cases were established, it became possible to ask various "what-if" questions and probe the sensitivity of production costs as a function of different operating parameters.

The primary difference among the cases is in the lignin processing stage. In the first kraft case, LMW lignin is isolated and then converted to pulping catalysts as outlined above. The second kraft-based approach modifies the first by eliminating the isolation of a LMW lignin fraction. Instead, the lignin is converted using known commercial technology to a crude mixture of two known compounds, vanillin and syringaldehyde (V/S). The V/S mixture is then treated with the same two-step chemical processing sequence as the first base case. This approach was evaluated because laboratory results indicated that V/S could be converted to benzoquinone more efficiently than LMW lignin. However, producing vanillin from lignin is a low-yield, expensive process that takes place under severe conditions. This base case probes whether the lower efficiency in the V/S production step can be offset by greater efficiency in the conversion to pulping catalyst.

The organosolv case uses lignin produced by solvent fractionation of lignocellulose, followed by the two-step chemical conversion into pulping catalysts. Isolating a LMW fraction is not necessary in this case because organosolv lignin tends to be lower in molecular weight than kraft lignin.

The analysis, which is commonly known as preliminary chemical-process design, involves a number of steps:

- Drawing a flow diagram for each base case,
- Calculating the material balance,
- Calculating the energy balance,
- Estimating equipment sizes,
- Estimating capital costs,
- Estimating operating costs,
- Evaluating the economics and potential profitability,
- Defining and evaluating variations of the base cases, and
- Developing conclusions and recommendations.

The degree of detail in each step can vary considerably, usually depending on the availability and quality of basic process-chemistry information. Approximate, short-cut design and costing methods are used because they conserve time and are more than adequate to identify areas for further research or more detailed calculations.

Results Favor Processes That Use Non-V/S Kraft Lignin and Organosolv Lignin

The initial evaluation of the three base cases was performed using several key technical assumptions (table B-1), which are based on small-scale laboratory research. The analysis, conducted Arthur J. Power and Associates, was based on a hypothetical, new production plant and facilities located in the southeastern United States during the third quarter of 1994, which could produce 19.3 million pounds of pulping catalysts per year. Capital costs were based on process design, material and energy balances, and major equipment specifications. Raw material and operating costs were based on technical specifications and current input costs.

The initial economic evaluation gave several interesting conclusions. First, the base case producing pulping catalysts from an intermediate V/S mixture did not compare favorably with the other two processes, because of a high projected amortized production cost of slightly greater than $4 per pound (figure B-1). In contrast, both the kraft case (without the intermediate V/S step) and the organosolv case appear viable, with amortized production costs of $1.24 and 79 cents per pound, respectively (tables B-2 and B-3).

An analysis was also made of competing methods that could be used to make AQ to see how a lignin-based route would fit into the market. Five petrochemical-based processes--using styrene, naphthalene, benzene, phthalic anhydride, and anthracene--were identified from the open and patent literature. All five are, or have been, used for commercial AQ synthesis and were judged to be the most serious competitors to the lignin-based process. The analysis calculated total raw material costs for each process, with estimated values for utilities, operating costs, and capital charges based on similar processes. The usual detailed work on preliminary process designs, capital and operating cost estimates, and profitability calculations was not done. The approximate results, however, are good enough to rank the processes on potential sales price (figure B-2). The lignin-to-AQ route was potentially the most cost effective of all those analyzed.

Further Technical Refinements Yield Additional Progress

A number of lignin processing techniques to separate the LMW fractions have been examined. Recent results indicate that simple solvent extraction of either kraft or organosolv lignin provides significant amounts of LMW material that can be converted to benzoquinones in the chemical processing stage. Supercritical fluid extraction, using carbon dioxide and a small amount of organic solvent, has been used to remove LMW lignin from pulping liquor (13). While the selectivity for LMW lignin was good, the yield was low.

A number of oxidizing agents have been studied for use in the first step of the chemical processing stage. Initially, hydrogen peroxide was examined. It has a number of attractive features; it is inexpensive, environmentally benign, and well established in the chemical and paper industries. However, early research generated low yields of benzoquinones. In contrast, more recent work indicates that both kraft LMW and organosolv lignin can be oxidized to benzoquinones using hydrogen peroxide and a catalyst.

Table B-1--Technical assumptions used for evaluating the three base cases

Case		
Kraft lignin	Kraft lignin through V/S intermediates	Organosolv lignin
Lignin supplied from seven kraft mills that have a pulp output of 1,500 tons per day. Ten percent of the lignin fraction was diverted from fuel use to production of pulping catalysts.[1]	Lignin supplied from seven kraft mills that have a pulp output of 1,500 tons per day. Ten percent of the lignin fraction was diverted from fuel use to production of pulping catalysts.[1]	Lignin collected as part of normal pulping operation
	V/S produced in 15 percent chemical yield	
Oxidation to benzoquinone has 20 percent chemical yield	V/S converted to benzoquinone in 80 percent chemical yield	Oxidation to benzoquinones has 40 percent chemical yield
Isoprene reaction has 80 percent chemical yield	Isoprene reaction has 90 percent chemical yield	Isoprene reaction has 50 percent chemical yield

[1]Diverting 10 percent of the lignin fraction from fuel use will still leave enough lignin available to burn in the chemical-recovery furnace.

Figure B-1

Kraft and Organosolv Cases Appear Viable

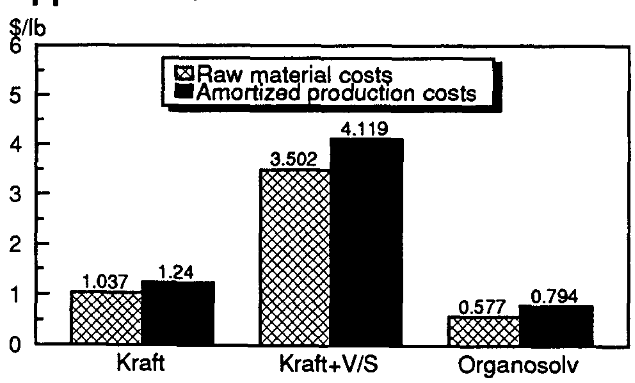
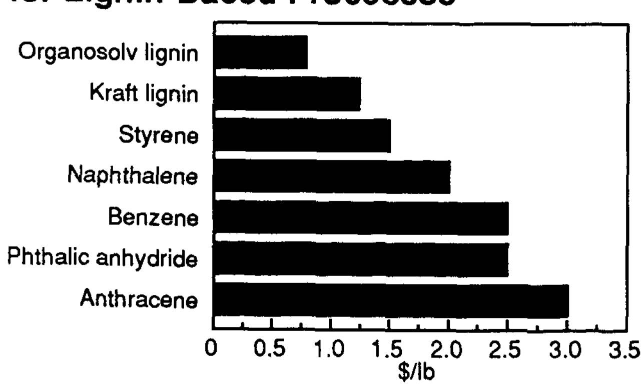


Figure B-2

Estimated Production Costs Lowest for Lignin-Based Processes



Another promising oxidizing agent is nitrogen dioxide. In the presence of oxygen, nitrogen dioxide effectively oxidizes about 60 percent of LMW hardwood lignin to benzoquinones. A third possibility was recently developed that directly oxidizes whole lignin without prior extraction of the LMW fraction. Samples of whole lignin were treated with metal salts in the presence of a base and then oxidized with nitrogen dioxide and oxygen. This increased the yield of benzoquinones. Additional research is underway to improve the method and develop milder and more efficient conditions for oxidation.

The second chemical processing step (adding isoprene) also can be improved with proper catalysts. Catalyzed reactions, as well as reactions carried out in water or mixtures of water and organic solvents, produce a number of materials, including dimethylanthraquinone, with good conversion of the starting benzoquinone. Analysis of these mixtures shows the presence of up to 25 percent dimethylanthraquinone.

Research Continues

The research undertaken thus far has demonstrated the feasibility of each step in the overall process under certain cost constraints on a small scale in the laboratory. The objective of present research is to develop and optimize lignin extraction and chemical conversion efficiencies to further lower the cost of pulping catalysts made from lignin. The program also is moving to demonstrate the

Table B-2--Costs of producing pulping catalysts from kraft LMW lignin in a hypothetical, new 19.3-million-pound production plant and facilities in the southeastern United States, third quarter 1994

Item	Units used per year	Cost per unit	Total annual cost	Annual cost per pound of production
	Pounds	Dollars	Thousand dollars	Dollars
Production costs:				
Raw materials--				
LMW lignin 1/	57,592,000	0.180	10,367	0.537
Methanol	13,520,000	0.100	1,352	0.070
Oxygen	1,237,000	0.025	31	0.002
Nitric oxide	3,552,000	0.300	1,066	0.055
Isoprene	25,264,000	0.285	7,200	0.373
Total raw material costs			20,015	1.037
Utilities--				
	Kilowatt hours			
Electric power	787,200	0.035	28	
	Million pounds			
Steam 2/	110,900	3.900	433	
	Million gallons			
Cooling water	1,344,000	0.060	81	
Total utility costs			542	0.028
Operating costs and expenses--				
	Workers			
Operating labor	12	28,700	344	
Foremen	4	32,500	130	
Supervisor	1	40,000	40	
Direct overhead 3/			325	
Maintenance 4/			275	
General plant overhead 5/			513	
Insurance and property taxes 6/			132	
Total operating costs and expenses			1,760	0.091
Total cash cost of production			22,317	1.156
Annual capital charges 7/			1,610	0.083
Total amortized manufacturing cost			23,927	1.240

1/ Cost of 18 cents per pound based on the fuel value of the contained organics in the kraft black liquor plus processing costs. 2/ 150 pounds-per-square-inch gauge. 3/ 45 percent of operating labor costs plus supervision (foremen and supervisor) costs. 4/ 4 percent of inside-battery-limit costs. 5/ 65 percent of operating costs. 6/ 1.5 percent of total fixed investment ($8,794,000). 7/ 15 percent of total utilized investment ($10,735,600) per year.

Table B-3--Costs of producing pulping catalysts from organsolv lignin in a hypothetical, new 19.3-million-pound production plant and facilities in the southeastern United States, third quarter 1994

Item	Units used per year	Cost per unit	Total annual cost	Annual cost per pound of production
	Pounds	Dollars	Thousand dollars	Dollars
Production costs:				
Raw materials--				
LMW lignin 1/	69,552,000	0.016	1,113	0.058
Methanol	16,232,000	0.100	1,623	0.084
Oxygen	1,341,000	0.025	34	0.002
Nitric oxide	3,856,000	0.300	1,157	0.060
Isoprene	25,264,000	0.285	7,200	0.373
Total raw material costs			11,127	0.577
Utilities--				
	Kilowatt hours			
Electric power	787,200	0.035	28	
	Million pounds			
Steam 2/	110,900	3.900	433	
	Million gallons			
Cooling water	1,344,000	0.060	81	
Total utility costs			542	0.028
Operating costs and expenses--				
	Workers			
Operating labor	12	28,700	344	
Foremen	4	32,500	130	
Supervisor	1	40,000	40	
Direct overhead 3/			325	
Maintenance 4/			275	
General plant overhead 5/			513	
Insurance and property taxes 6/			132	
Total operating costs and expenses			1,759	0.091
Total cash cost of production			13,427	0.696
Annual capital charges 7/			1,901	0.099
Total amortized manufacturing cost			15,329	0.794

1/ Cost of 1.6 cents per pound based on purchase of wood chips at $60 per dry ton and sale of byproduct cellulose pulp at $300 per ton. 2/ 150 pounds-per-square-inch gauge. 3/ 45 percent of operating labor costs plus supervision (foreman and supervisor) costs. 4/ 4 percent of inside-batter-limit costs. 5/ 65 percent of operating costs. 6/ 1.5 percent of total fixed investment ($8,780,000). 7/ 15 percent of total utilized investment ($12,675,000) per year.

successful results of the laboratory research on a larger scale, with the goal of producing between 1.0 and 1.5 pounds of an active pulping catalyst mixture. An important component of the near-term work will be testing the catalyst mixtures under actual pulping conditions.

Preparation of AQ and other pulping catalysts from lignin looks to be a promising new direction for lignin use. However, it is only one possible material that potentially can be produced from lignin. In the future, the NREL-IPST program may be expanded to evaluate the production of other lignin-derived, high-value chemicals.

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List of Tables

Table 3--Total fats and oils consumption, with inedible by category, United States, 1986/87-93

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1986/87	d	d	5,990.6	d	d	d	d	d	d	d
1987/88	20,241.2	14,175.5	6,065.7	868.6	179.1	1,967.6	196.3	107.8	2,203.8	542.8
1988/89	19,426.7	13,542.0	5,884.7	744.5	180.3	2,079.3	202.3	115.8	2,074.1	488.4
1989/90	20,036.0	14,382.7	5,653.3	792.0	89.5	2,143.5	222.4	157.1	1,944.7	304.1
1991	20,332.1	14,613.0	5,719.1	832.9	106.8	1,974.0	182.6	101.7	2,234.7	286.4
1992	20,751.7	14,847.3	5,904.4	738.8	123.8	2,176.5	165.5	109.4	2,041.2	549.3
1993	21,590.4	15,744.7	5,845.7	748.5	125.2	2,199.5	170.2	116.0	1,897.6	588.7

d = Data withheld to avoid disclosing figures for individual companies.
1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.
Source: Bureau of Census.

Table 4--Castor oil consumption, with inedible by category, United States, 1986/87-93

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1986/87	70.4	0.0	70.4	d	4.6	0.0	4.2	5.6	d	53.8
1987/88	74.6	0.0	74.6	d	4.3	0.0	4.8	6.1	d	59.0
1988/89	59.2	0.0	59.2	d	4.8	0.0	4.5	6.2	0.0	43.2
1989/90	51.4	0.0	51.4	d	5.9	0.0	4.0	5.7	0.0	d
1991	46.0	0.0	46.0	d	5.9	0.0	4.0	d	0.0	31.7
1992	41.3	0.0	41.3	d	d	0.0	3.3	3.5	0.0	28.4
1993	54.2	0.0	54.2	d	d	0.0	3.5	2.8	0.0	37.8

d = Data withheld to avoid disclosing figures for individual companies.
1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.
Source: Bureau of Census.

Table 5--Coconut oil consumption, with inedible by category, United States, 1986/87-93

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1986/87	858.2	319.4	538.8	216.1	d	0.0	d	d	95.7	d
1987/88	788.6	233.4	555.4	213.8	d	0.0	7.2	d	131.4	d
1988/89	688.8	211.2	477.6	130.6	1.4	d	14.6	d	121.9	206.6
1989/90	525.2	160.6	364.6	156.9	2.1	0.0	9.7	4.0	134.6	57.3
1991	815.6	153.0	662.6	158.0	d	d	2.4	d	426.7	72.8
1992	875.4	176.3	699.1	121.7	d	0.0	3.2	d	d	d
1993	936.3	218.0	718.3	132.0	d	0.0	3.1	d	d	d

d = Data withheld to avoid disclosing figures for individual companies.
1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.
Source: Bureau of Census.

Table 6--Edible tallow consumption, with inedible by category, United States, 1986/87-93

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1986/87	979.2	910.6	68.6	d	0.0	0.0	d	d	d	d
1987/88	954.3	863.6	90.5	d	0.0	0.0	d	d	d	d
1988/89	923.3	779.2	144.1	d	0.0	d	d	d	d	d
1989/90	846.4	706.3	140.1	113.9	0.0	d	d	d	d	d
1991	611.8	463.1	148.7	d	0.0	d	d	d	d	d
1992	595.0	429.3	165.7	d	0.0	d	d	d	d	d
1993	562.1	408.9	153.2	d	0.0	d	d	d	d	d

d = Data withheld to avoid disclosing figures for individual companies.
1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.
Source: Bureau of Census.

Table 7--Inedible tallow consumption, with inedible by category, United States, 1986/87-93

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
	--Million pounds--									
1986/87	3,040.9	0.0	3,040.9	543.6	0.0	1,698.9	0.0	70.3	693.6	35.1
1987/88	3,137.8	0.0	3,137.8	502.0	0.0	1,820.3	0.0	69.9	712.6	33.0
1988/89	3,086.7	0.0	3,086.7	374.9	0.0	1,925.4	0.0	70.3	680.0	36.1
1989/90	3,219.0	0.0	3,219.0	398.4	0.0	1,982.9	0.0	109.0	684.0	44.7
1991	2,949.3	0.0	2,949.3	391.5	0.0	1,748.4	0.0	59.6	700.9	48.9
1992	3,050.1	0.0	3,050.1	334.4	0.0	1,954.4	0.0	63.2	659.0	39.1
1993	3,018.2	0.0	3,018.2	299.6	0.0	1,994.7	0.0	71.5	615.1	37.3

d = Data withheld to avoid disclosing figures for individual companies.
1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.
Source: Bureau of Census.

Table 8--Lard consumption, with inedible by category, United States, 1986/87-93

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
	--Million pounds--									
1986/87	301.2	240.9	60.3	d	0.0	d	0.0	6.2	d	d
1987/88	347.5	280.3	66.9	d	0.0	d	0.0	8.4	d	d
1988/89	389.9	324.5	65.4	0.0	0.0	d	0.0	d	d	d
1989/90	369.3	303.8	65.5	d	0.0	d	0.0	9.1	d	d
1991	393.1	313.8	79.3	0.0	0.0	d	0.0	5.7	d	4.1
1992	479.7	345.0	134.6	0.0	0.0	d	0.0	10.9	d	13.5
1993	473.3	324.6	149.7	0.0	0.0	d	0.0	8.6	d	28.7

d = Data withheld to avoid disclosing figures for individual companies.
1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.
Source: Bureau of Census.

Table 9--Linseed oil consumption, with inedible by category, United States, 1986/87-93

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
	--Million pounds--									
1986/87	280.8	0.0	280.8	0.0	187.6	0.0	d	d	d	d
1987/88	159.3	0.0	159.3	0.0	85.5	0.0	31.0	d	d	40.5
1988/89	154.9	0.0	154.9	0.0	101.6	0.0	23.1	d	d	28.2
1989/90	110.5	0.0	110.5	0.0	30.3	d	52.5	d	d	23.8
1991	95.8	0.0	95.8	0.0	40.7	0.0	41.6	d	d	12.7
1992	154.4	0.0	154.4	0.0	69.0	0.0	31.3	d	d	d
1993	125.8	0.0	125.8	0.0	66.9	0.0	25.4	d	d	d

d = Data withheld to avoid disclosing figures for individual companies.
1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.
Source: Bureau of Census.

Table 10--Palm oil consumption, with inedible by category, United States, 1986/87-93

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
	--Million pounds--									
1986/87	317.9	278.7	39.2	d	d	d	d	d	d	d
1987/88	242.6	197.5	45.1	d	d	d	d	d	d	d
1988/89	247.0	203.8	43.2	d	0.0	d	d	0.0	d	d
1989/90	177.7	124.0	53.7	d	0.0	d	0.0	d	d	d
1991	d	d	d	d	0.0	d	0.0	d	d	d
1992	220.5	108.1	112.4	d	0.0	d	0.0	d	40.6	3.6
1993	192.3	76.2	116.1	d	0.0	d	0.0	d	37.2	5.3

d = Data withheld to avoid disclosing figures for individual companies.
1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.
Source: Bureau of Census.

Table 11--Rapeseed oil consumption, with inedible by category, United States, 1989/90-93 1/

Year 2/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1989/90	d	265.0	d	0.0	d	d	d	d	d	d
1991	d	285.1	d	0.0	0.0	d	0.0	d	d	d
1992	d	360.5	d	0.0	0.0	d	0.0	d	d	d
1993	d	362.5	d	0.0	0.0	0.0	0.0	d	d	d

d = Data withheld to avoid disclosing figures for individual companies.

1/ Includes both canola and industrial rapeseed. 2/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 3/ Includes similar oils.

Source: Bureau of Census.

Table 12--Soybean oil consumption, with inedible by category, United States, 1986/87-93

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1986/87	10,512.2	10,212.7	299.5	d	63.2	d	109.2	d	d	65.3
1987/88	10,714.5	10,429.1	285.3	2.7	54.1	d	106.1	d	d	72.3
1988/89	9,917.6	9,635.8	281.8	1.5	34.9	d	123.7	d	d	68.2
1989/90	10,808.3	10,536.7	271.6	d	38.2	d	112.4	d	d	52.4
1991	11,267.7	10,966.7	301.0	d	49.2	d	104.7	d	d	40.4
1992	11,471.6	11,168.7	302.8	d	43.5	22.3	94.0	5.9	d	69.8
1993	12,495.6	12,200.9	294.7	d	38.7	23.7	98.1	5.8	d	65.8

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 13--Tall oil consumption, with inedible by category, United States, 1986/87-93

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1986/87	1,227.0	0.0	1,227.0	12.2	d	0.0	15.7	12.9	1,152.6	19.2
1987/88	1,269.4	0.0	1,269.4	16.8	23.3	0.0	20.9	9.6	1,181.1	17.8
1988/89	1,234.3	0.0	1,234.3	8.3	31.8	0.0	18.0	8.1	1,157.3	10.8
1989/90	1,024.7	0.0	1,024.7	8.4	7.4	0.0	21.7	7.1	969.9	10.2
1991	940.0	0.0	940.0	3.5	5.4	0.0	11.6	4.0	906.5	9.0
1992	883.5	0.0	883.5	d	d	0.0	19.4	7.0	841.8	11.4
1993	891.8	0.0	891.8	d	d	0.0	23.0	6.3	806.9	d

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 14--Vegetable oil foots consumption, with inedible by category, United States, 1986/87-93

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1986/87	94.9	0.0	94.9	d	d	d	d	d	d	d
1987/88	91.1	0.0	91.1	d	d	74.3	d	d	d	d
1988/89	87.5	0.0	87.5	d	d	72.7	d	d	d	d
1989/90	100.1	0.0	100.1	d	d	81.7	d	d	d	d
1991	148.8	0.0	148.8	d	0.0	131.4	d	d	d	d
1992	134.9	0.0	134.9	d	0.0	120.2	0.0	d	d	d
1993	132.5	0.0	132.5	d	0.0	116.8	0.0	d	d	d

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 15--Linseed oil, U.S. imports, by country 1/

Exporting country	1993	Jan-Aug 94	Average
		--Kilograms--	
Canada	151,998	186,566	169,282
West Germany	2,600	2,394	2,497
Total	154,598	188,960	171,779

1/ Crude and refined, not chemically modified.

Source: Bureau of Census, Department of Commerce.

Table 16--Linseed oil, U.S. exports, by country 1/

Importing country	1993	Jan-Aug 94	Average
		--Kilograms--	
Canada	1,458,076	951,897	1,204,987
Mexico	639,484	223,815	431,650
Brazil	272,610	0	136,305
South Korea	176,545	57,456	117,001
Belize	97,710	130,155	113,933
France	0	185,170	92,585
Australia	129,600	51,445	90,523
Japan	135,470	10,137	72,804
Other	148,357	118,150	133,254
Total	3,057,852	1,728,225	2,393,039

1/ Crude and refined, not chemically modified.

Source: Bureau of Census, Department of Commerce.

Table 17--Castor oil, U.S. imports, by country 1/

Exporting country	1993	Jan-Aug 94	Average
		--Kilograms--	
India	32,046,325	27,521,479	29,783,902
Ecuador	4,070,548	2,776,522	3,423,535
Brazil	5,906,259	359,780	3,133,020
Other	49,342	42,864	46,103
Total	42,072,474	30,700,645	36,386,560

1/ Crude and refined, not chemically modified.

Source: Bureau of Census, Department of Commerce.

Table 18--Castor oil, U.S. exports, by country 1/

Importing country	1993	Jan-Aug 94	Average
		--Kilograms--	
Mexico	452,427	659,502	555,965
Canada	636,138	434,360	535,249
Other	125,178	88,458	106,823
Total	1,213,743	1,182,320	1,198,037

1/ Crude and refined, not chemically modified.

Source: Bureau of Census, Department of Commerce.

Table 19--Tung oil, U.S. imports by country 1/

Exporting country	1993	Jan-Aug 94	Average
		--Kilograms--	
Argentina	2,136,530	1,036,240	1,586,385
China	546,146	430,616	488,381
Other	30,400	15,200	22,800
Total	2,713,076	1,482,056	2,097,566

1/ Whether or not refined, not chemically modified.

Source: Bureau of Census, Department of Commerce.

Table 20--Tung oil, U.S. exports by country 1/

Importing country	1993	Jan-Aug 94	Average
		--Kilograms--	
Canada	168,927	88,338	128,633
Mexico	102,039	54,862	78,451
Other	19,764	0	9,882
Total	290,730	143,200	216,966

1/ Whether or not refined, not chemically modified.

Source: Bureau of Census, Department of Commerce.

Table 21--Jojoba oil, U.S. imports, by country 1/

Exporting country	1993	Jan-Aug 94	Average
		--Kilograms--	
Mexico	121,448	132,045	126,747
Canada	18,155	4,906	11,531
Other	2,830	0	1,415
Total	142,433	136,951	139,693

1/ Whether or not refined, not chemically modified.

Source: Bureau of Census, Department of Commerce.

Table 22--Jojoba oil, U.S. exports, by country 1/

Importing country	1993	Jan-Aug 94	Average
		--Kilograms--	
West Germany	197,382	104,908	151,145
Japan	91,220	59,675	75,448
France	40,210	23,595	31,903
Other	13,999	15,790	14,897
Total	342,811	203,968	273,393

1/ Whether or not refined, not chemically modified.

Source: Bureau of Census, Department of Commerce.

Table 23--Peat, U.S. imports, by country 1/

Exporting country	1993	Jan-Aug 94	Average
		--Metric tons--	
Canada	644,695	468,662	556,679
Finland	2,309	3,320	2,815
Other	884	434	660
Total	647,888	472,416	560,154

1/ Including peat litter, whether or not agglomerated.

Source: Bureau of Census, Department of Commerce.

Table 24--Peat, U.S. exports, by country 1/

Importing country	1993	Jan-Aug 94	Average
		--Metric tons--	
Mexico	4,450	5,594	5,022
Canada	704	1,817	1,261
Other	2,201	4,164	3,185
Total	7,355	11,575	9,468

1/ Including peat litter, whether or not agglomerated.

Source: Bureau of Census, Department of Commerce.

Table 25--Flax, raw or retted, U.S. imports, by country

Exporting country	1993	Jan-Aug 94	Average
		--Kilograms--	
Canada	1,545,880	0	772,940
Other	142	250	196
Total	1,546,022	250	773,136

Source: Bureau of Census, Department of Commerce.

Table 26--Flax, raw or retted, U.S. exports, by country

Importing country	1993	Jan-Aug 94	Average
		--Kilograms--	
Honduras	10,035	0	5,018
Brazil	4,907	0	2,454
Total	14,942	0	7,471

Source: Bureau of Census, Department of Commerce.

Table 27--Flax, broken, scutched, hackled or otherwise processed, but not spun, U.S. imports, by country

Exporting country	1993	Jan-Aug 94	Average
		--Kilograms--	
France	62,311	689,487	375,899
Belgium	91,859	54,143	73,001
Other	61	145	103
Total	154,231	743,775	449,003

Source: Bureau of Census, Department of Commerce.

Table 28--Flax, broken, scutched, hackled or otherwise processed, but not spun, U.S. exports, by country

Importing country	1993	Jan-Aug 94	Average
		--Kilograms--	
Canada	19,235	7,825	13,530
Japan	1,466	454	960
Other	297	379	339
Total	20,998	8,658	14,829

Source: Bureau of Census, Department of Commerce.

Table 29--Flax tow and waste, U.S. imports, by country 1/

Exporting country	1993	Jan-Aug 94	Average
		--Kilograms--	
Canada	31,540,177	26,841,256	29,190,717
Belgium	10,760,918	7,770,436	9,265,677
Other	3,021,849	1,268,000	2,144,925
Total	45,322,944	35,879,692	40,601,319

1/ Including yarn waste and garnetted stock.

Source: Bureau of Census, Department of Commerce.

Table 30--Flax tow and waste, U.S. exports, by country 1/

Importing country	1993	Jan-Aug 94	Average
		--Kilograms--	
Dominican Republ	36,639	0	18,320
Australia	28,558	0	14,279
Other	8,055	0	4,028
Total	73,252	0	36,627

1/ Including yarn waste and garnetted stock.

Source: Bureau of Census, Department of Commerce.

Table 31--Cattle hides, whole, fresh or wet-salted, U.S. imports, by country

Exporting country	1993	Jan-Aug 94	Average
		--Pieces--	
Canada	1,481,122	1,038,928	1,260,025
Mexico	85,185	62,765	73,975
Ireland	21,020	0	10,510
Finland	8,286	0	4,143
Other	11,324	1,520	6,423
Total	1,606,937	1,103,213	1,355,076

Source: Bureau of Census, Department of Commerce.

Table 32--Cattle hides, whole, fresh or wet-salted, U.S. exports, by country

Importing country	1993	Jan-Aug 94	Average
		--Pieces--	
South Korea	7,851,241	5,004,486	6,427,864
Japan	4,167,324	2,086,950	3,127,137
Mexico	2,035,137	1,038,194	1,536,666
Other	1,796,688	1,685,047	902,978
Total	15,850,390	9,814,677	11,994,645

Source: Bureau of Census, Department of Commerce.

Table 33--Sheep or lamb skins, wool-on, U.S. imports, by country 1/

Exporting country	1993	Jan-Aug 94	Average
		--Pieces--	
Mexico	99,169	19,444	59,307
Canada	69,411	46,720	58,066
Australia	28,107	57,782	42,945
Other	26	6,150	3,088
Total	196,713	130,096	163,406

1/ Fresh, salted, dried, limed, pickled, or otherwise perserved but not tanned.

Source: Bureau of Census, Department of Commerce.

Table 34--Sheep or lamb skins, wool-on, U.S. exports, by country 1/

Importing country	1993	Jan-Aug 94	Average
		--Pieces--	
Italy	327,300	225,244	276,272
South Korea	251,462	65,089	158,276
Mexico	231,330	34,356	132,843
France	152,441	53,857	103,149
Other	161,823	114,448	138,138
Total	1,124,356	492,994	808,678

1/ Fresh, salted, dried, limed, pickled, or otherwise perserved but not tanned.

Source: Bureau of Census, Department of Commerce.

Table 35--Bovine upper leather, whole, without hair, U.S. imports, by country 1/

Exporting country	1993	Jan-Aug 94	Average
		--Square meters--	
Argentina	429,499	42,265	235,882
Brazil	24,765	41,406	33,086
France	24,444	25,405	24,925
Mexico	31,173	2,401	16,787
Other	14,115	11,498	12,807
Total	523,996	122,975	323,486

1/ With a surface area not exceeding 2.6 square meters.

Source: Bureau of Census, Department of Commerce.

Table 36--Bovine lining leather, whole, without hair, U.S. imports, by country 1/

Exporting country	1993	Jan-Aug 94	Average
		--Square meters--	
Brazil	284,477	172,768	228,623
Kenya	49,213	15,444	32,329
Bangladesh	24,122	24,908	24,515
Other	11,131	21,743	16,439
Total	368,943	234,863	301,906

1/ With a surface area not exceeding 2.6 square meters.

Source: Bureau of Census, Department of Commerce.

Table 37--Bovine upper leather, whole, without hair, U.S. exports, by country 1/

Importing country	1993	Jan-Aug 94	Average
		--Square meters--	
Hong Kong	5,586,120	281,514	2,933,817
Dom. Republic	2,660,528	531,373	1,595,951
West Germany	1,861,526	14,043	937,785
South Korea	1,115,223	52,463	583,843
Other	4,072,025	199,899	2,135,969
Total	15,295,422	1,079,292	8,187,365

1/ With a surface area not exceeding 2.6 square meters.

Source: Bureau of Census, Department of Commerce.

Table 38--Sheep or lamb skin leather, without wool, U.S imports, by country 1/

Exporting country	1993	Jan-Aug 94	Average
		--Square meters--	
France	8,658	14	4,336
Italy	1,032	915	974
Mexico	415	1,461	938
Total	10,105	2,390	6,248

1/ Vegetable pretanned.

Source: Bureau of Census, Department of Commerce.

Table 39--Sheep or lamb skin leather, without wool, U.S. exports, by country 1/

Importing country	1993	Jan-Aug 94	Average
	--Square meters--		
South Korea	10,453	0	5,227
Italy	4,602	0	2,301
Mexico	3,288	0	1,644
Chile	0	2,702	1,351
Other	1,604	0	802
Total	19,947	2,702	11,325

1/ Vegetable pretanned.

Source: Bureau of Census, Department of Commerce.

Table 40--Swine leather, without hair, U.S. imports, by country

Exporting country	1993	Jan-Aug 94	Average
	--Square meters--		
China	511,501	163,558	337,530
Japan	485,066	168,442	326,754
West Germany	156,155	22,364	89,260
Hong Kong	107,128	35,543	71,336
Mexico	35,173	10,754	22,964
Czech Republic	19,336	8,678	14,007
Other	40,226	25,113	32,670
Total	1,354,585	434,452	894,519

Source: Bureau of Census, Department of Commerce.

Table 41--Swine leather, without hair, U.S. exports, by country

Importing country	1993	Jan-Aug 94	Average
	--Square meters--		
Dom. Republic	1,445,887	1,207,698	1,326,793
Canada	1,109,962	628,187	869,075
Chile	811,182	374,837	593,010
Hong Kong	581,819	397,020	489,420
Costa Rica	499,207	356,615	427,911
Mexico	236,928	345,525	291,227
Other	781,968	602,802	692,389
Total	5,466,953	3,912,684	4,689,825

Source: Bureau of Census, Department of Commerce.

Table 42--Newsprint, in rolls or sheets, U.S. imports, by country

Exporting country	1993	Jan-Aug 94	Average
	--Metric tons--		
Canada	6,922,007	4,597,585	5,759,796
Finland	19,011	8,698	13,855
Other	3,182	1,362	2,272
Total	6,944,200	4,607,645	5,775,923

Source: Bureau of Census, Department of Commerce.

Table 43--Newsprint, in rolls or sheets, U.S. exports, by country

Importing country	1993	Jan-Aug 94	Average
	--Metric tons--		
Japan	293,136	192,295	242,716
Mexico	129,636	113,008	121,322
Malaysia	57,626	49,539	53,583
Hong Kong	51,631	32,236	41,934
South Korea	41,469	12,842	27,156
China	34,841	7,987	21,414
Other	142,283	81,439	111,873
Total	750,622	489,346	619,998

Source: Bureau of Census, Department of Commerce.

Table 44--Kraftliner, uncoated, bleached, in rolls or sheets, U.S. exports, by country

Importing country	1993	Jan-Aug 94	Average
	--Kilograms--		
Mexico	2,421,621	833,448	1,627,535
Japan	2,234,768	318,116	1,276,442
Canada	1,559,739	26,000	792,870
Colombia	1,281,751	55,759	668,755
Ecuador	54,393	1,050,851	552,622
Guatemala	607,682	72,331	340,007
Egypt	629,368	0	314,684
China	0	614,191	307,096
Other	2,082,694	723,788	1,403,244
Total	10,872,016	3,694,484	7,283,255

Source: Bureau of Census, Department of Commerce.

Table 45--Kraftliner, uncoated, bleached, in rolls or sheets, U.S. imports, by country

Exporting country	1993	Jan-Aug 94	Average
	--Kilograms--		
Canada	85,895,507	79,629,158	82,762,333
Finland	338,403	3,007,655	1,673,029
Other	699	1,000	850
Total	86,234,609	82,637,813	84,436,212

Source: Bureau of Census, Department of Commerce.

Table 46--Kraftliner, uncoated, unbleached, in rolls or sheets, U.S. imports, by country

Exporting country	1993	Jan-Aug 94	Average
	--Kilograms--		
Canada	108,941,364	70,759,640	89,850,502
West Germany	2,186,396	78,881	1,132,639
Total	111,127,760	70,838,521	90,983,141

Source: Bureau of Census, Department of Commerce.

Table 47--Kraftliner, uncoated, unbleached, in rolls or sheets, U.S. exports, by country

Importing country	1993	Jan-Aug 94	Average
		--Kilograms--	
Hong Kong	322,342,833	256,939,948	289,641,391
China	246,361,063	197,393,439	221,877,251
Ecuador	158,093,595	120,648,832	139,371,214
Costa Rica	165,928,301	105,506,654	135,717,478
Italy	130,325,345	115,812,812	123,069,079
Canada	155,779,694	89,755,772	122,767,733
West Germany	134,249,686	92,857,743	113,553,715
Other	689,464,245	542,891,990	616,178,118
Total	2,002,544,762	1,521,807,190	1,762,175,976

Source: Bureau of the Census.

Table 48--Sack kraft paper, uncoated, bleached, in rolls or sheets, U.S. exports, by country

Importing country	1993	Jan-Aug 94	Average
		--Kilograms--	
Mexico	3,879,270	3,015,682	3,447,476
Canada	3,950,000	2,553,000	3,251,500
Iran	499,230	699,880	599,555
Argentina	0	802,323	401,162
Other	614,075	931,476	772,779
Total	8,942,575	8,002,361	8,472,472

Source: Bureau of Census, Department of Commerce.

Table 49--Sack kraft paper, uncoated, bleached in rolls or sheets, U.S. imports, by country

Exporting country	1993	Jan-Aug 94	Average
		--Kilograms--	
Finland	61,805	132,824	97,315
Canada	82,184	85,622	83,903
Other	13,200	9,224	11,212
Total	157,189	227,670	192,430

Source: Bureau of Census, Department of Commerce.

Table 50--Sack kraft paper, uncoated, unbleached, rolls or sheets, U.S. imports, by country

Exporting country	1993	Jan-Aug 94	Average
		--Kilograms--	
Canada	36,758,508	28,999,296	32,878,902
France	4,571	0	2,286
Finland	0	4,430	2,215
Other	0	558	279
Total	36,763,079	29,004,284	32,883,682

Source: Bureau of Census, Department of Commerce.

Table 51--Sack kraft paper, uncoated, unbleached, in rolls or sheets, U.S. exports, by country

Importing country	1993	Jan-Aug 94	Average
		--Kilograms--	
Canada	13,646,514	9,048,215	11,347,365
Malaysia	8,590,525	9,359,630	8,975,078
Japan	7,929,609	5,084,465	6,507,037
Indonesia	4,962,792	2,496,831	3,729,812
Hong Kong	2,013,112	1,195,879	1,604,496
China	176,027	2,645,983	1,411,005
Guatemala	994,029	1,659,294	1,326,662
Other	3,748,274	6,205,734	4,977,004
Total	42,060,882	37,696,031	39,878,457

Source: Bureau of the Census.

Table 52--Natural rubber latex, whether or not prevulcanized, U.S. imports, by country

Exporting country	1993	Jan-Aug 94	Average
		--Kilograms--	
Malaysia	35,036,281	19,849,945	27,443,113
Indonesia	28,524,147	16,912,442	22,718,295
Guatemala	2,649,454	1,711,473	2,180,464
Other	667,532	110,933	389,234
Total	66,877,414	38,584,793	52,731,106

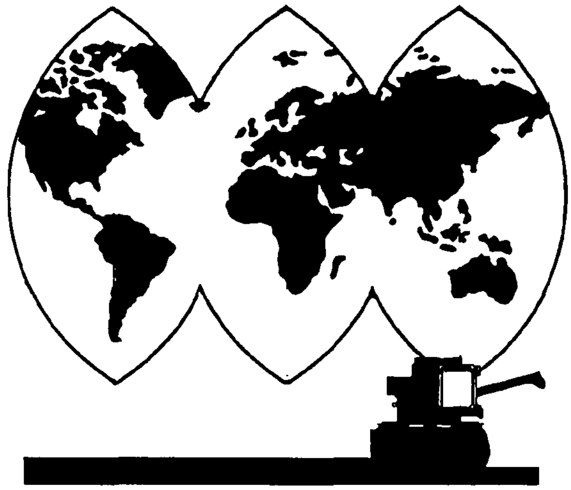
Source: Bureau of Census, Department of Commerce.

Table 53--Natural rubber latex, whether or not prevulcanized, U.S. exports, by country

Importing country	1993	Jan-Aug 94	Average
		--Kilograms--	
Mexico	1,241,693	2,072,599	1,657,146
Canada	1,882,458	533,465	1,207,962
Japan	893,141	877,916	885,529
Italy	720,700	205,121	462,911
Argentina	515,928	257,599	386,764
Hong Kong	260,811	140,973	200,892
Belgium	355,087	19,086	187,087
Other	702,514	548,142	625,335
Total	6,572,332	4,654,901	5,613,626

Source: Bureau of Census, Department of Commerce.

Global Environmental Policies Affect Agricultural Trade



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USDA TO HOLD AGRICULTURAL ECONOMIC OUTLOOK FORUM

The U.S. Department of Agriculture will hold its first agricultural economic forum on February 22 and 23, 1995, in Washington, D.C. The forum will replace the 70-year-old outlook conference that USDA traditionally held each December. Responding to feedback from outlook conference participants and information users, the conference is being redesigned to add a new longer-term focus that will help farmers, agribusiness, and policy officials make strategic decisions for the future.

Specific details on the forum will be announced later. To request a notice of program and registration details call 202-720-3050, fax 202-690-1805, or write to Outlook Forum, Room 5143 South Building, USDA, Washington, D.C. 20250-3800.